The Effects of Forest Harvesting on Marten and Small Mammals in Western Newfoundland

Report Prepared for
The Newfoundland and Labrador Wildlife Division
and
Corner Brook Pulp and Paper, Limited
(Kruger)

(FINAL REPORT)

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INTRODUCTION

Marten Population History

Historically, marten (Martes americana) were distributed throughout the boreal forests of North America (Hagmeier 1956). On the island of Newfoundland, marten were once found in most forested areas, although probably never in great numbers (Bergerud 1969, Snyder 1985). By the early 1900's, marten populations had begun to decline (Snyder 1985). Prior to 1934 they were trapped commercially, but by 1934 were sufficiently rare to necessitate the closing of the trapping season. It has never been reopened. In eastern Newfoundland, remnant populations of marten were probably extinct by 1969 (Bergerud 1969). In 1973, provincial Wildlife Division personnel considered the only remnant population of marten in Newfoundland to be concentrated in the Grand Lake-Little Grand Lake area of western Newfoundland; later distribution studies confirmed this (Mayo 1975, 1984; Snyder and Hancock 1982). As a result of rising concern, the Pine Marten Study Area (PMSA, Figure 1) was created in 1973 by the Newfoundland and Labrador Wildlife Division to protect the last remnant population. Within this area, which includes most of the high density marten area identified in 1985 (Snyder and Hancock 1985, Figure 2), all trapping and snaring were prohibited to protect marten from accidental capture. It was hoped that the PMSA would act as a refuge from which marten would eventually disperse and colonize other areas of suitable habitat. This apparently has not happened; however, relatively high densities of marten remain within the area. Marten were introduced into the headwaters area of the La Poile River (Mayo 1976a), the Main River

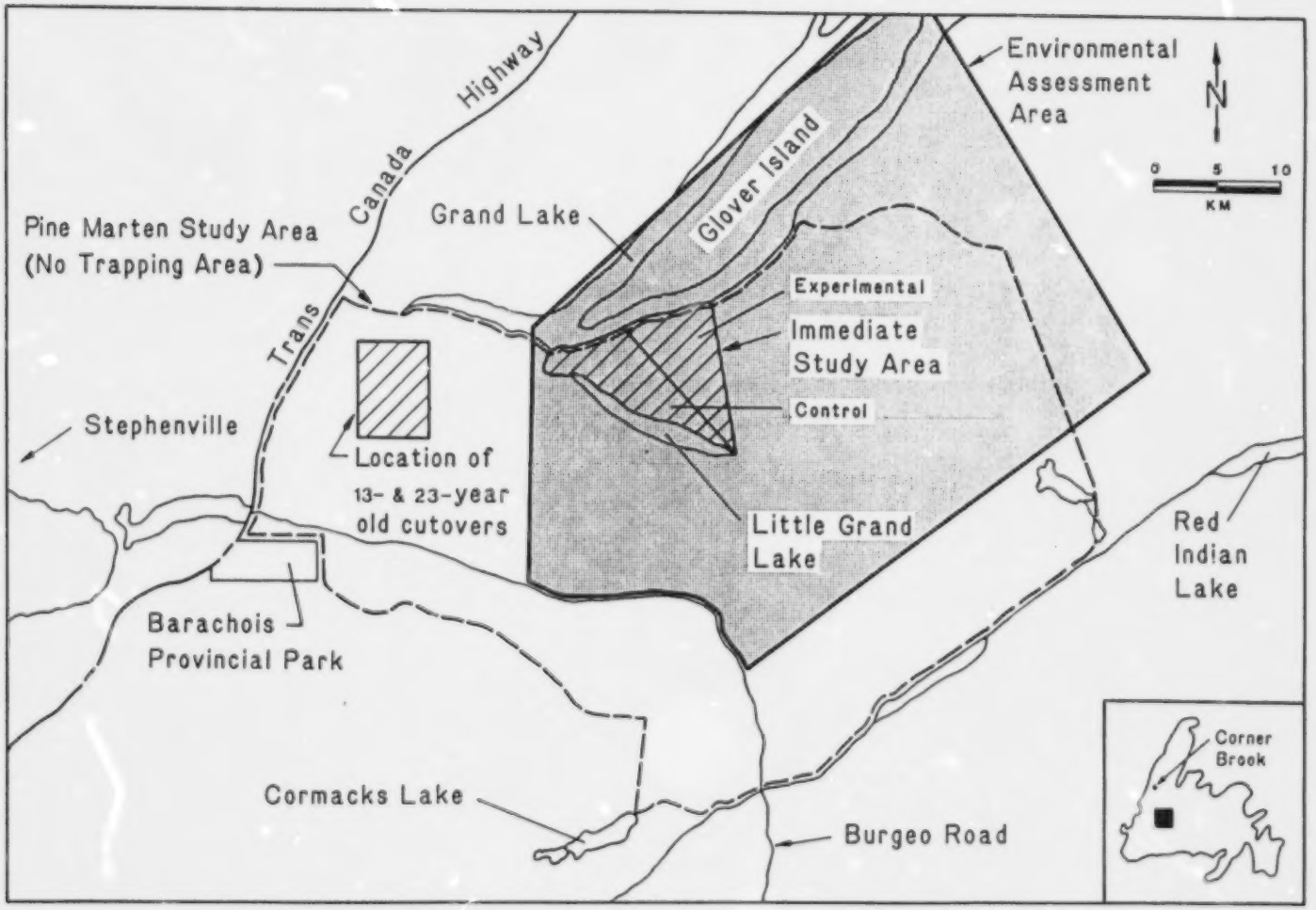


Figure 1. Pine marten study area in western Newfoundland.

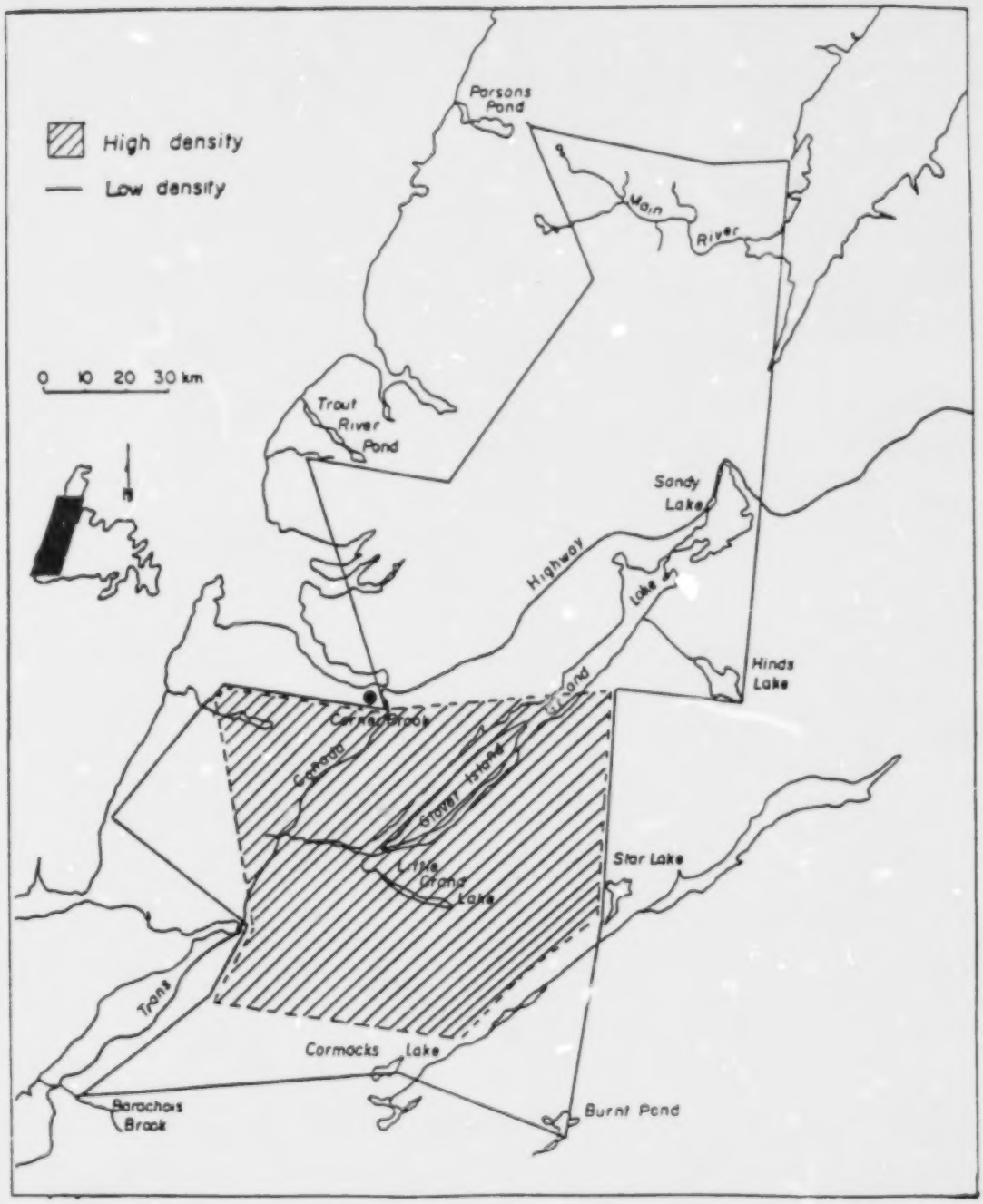


Figure 2. Relative density and distribution of marten in Newfoundland (from Hancock et al. 1985).

area (Mayo 1976b), Siviers Island (Porter 1976), and Terra Nova National Park (Bateman 1985) in attempts to establish other populations. It appears that the introductions to Siviers Island and La Poile River have been unsuccessful. Marten have been reported from the Main River area since 1976, but it is not certain if their presence is due to the introduction, or if they were there beforehand (Hancock, pers. comm. 1987). The introduction into Terra Nova National Park is still being assessed, but three of the eight marten relocated are known to have died after being accidentally caught in traps outside the Park. Due to the long term gradual decline resulting in drastic reductions in distribution and numbers, marten in Newfoundland were listed as "threatened" on the list of endangered wildlife in Canada in April 1986 (COSEWIC, 1986).

Major factors contributing to the early decline of marten in Newfoundland are thought to have been over-trapping and habitat loss due to logging and fire (Snyder 1985). Our studies also suggest the possibility of recurring disease. Habitat loss due to logging, accidental trappings, disease, environmental contamination from insecticides, and a naturally depauperate prey base may be hindering marten recovery. However, given their specific habitat requirements, habitat loss caused by extensive and contiguous clear-cutting within prime habitat currently is probably the main obstacle to recovery of the marten population on the island.

Marten prefer dense, mature coniferous forest or mixed forest with high overstory density (Bateman 1986, Clark and Campbell 1976, de Vos 1952, Douglass et al. 1983, Francis and Stephenson 1972, Hargis 1982, Koehler and Hornocker 1977, Koehler et al. 1975, Marshall 1951, Pulliainen 1981, Raine 1983, Soutiere 1979, Spencer et al. 1983). The reasons for this preference are not clearly understood, but overhead cover and prey abundance and

availability appear to be involved. Large clear-cuts have been shown to be detrimental to marten populations in North America and Europe (Campbell 1979, Grakov 1972, Major 1979, Snyder 1984, Soutiere 1979, Thompson 1982). In Wyoming, clear-cuts less than one year old were not used by marten (Clark and Campbell 1977), and regenerating clear-cuts in Maine were used only in the late summer when berries were present (Steventon and Major 1982). Commercially clear-cut areas in Maine supported densities two-thirds less than those found in similar uncut areas (Soutiere 1979). Clear-cut areas were found to be suboptimal habitat (Thompson 1986) that supported few marten in Ontario (de Vos 1952). In areas of extensive clear-cutting in Newfoundland, Snyder and Bissonette (1987) found marten concentrated their use in undisturbed forest while small, uncut residual stands greater than 15 hectares were used if available. Clear-cuts less than 15 years old were used minimally, while no evidence of marten use in clear-cuts 16 to 25 years old was noted. Lack of trap success may be due to a small trapping effort expended here.

History of the Mill

The Corner Brook Mill began producing paper in 1925 under a tripartite ownership involving the governments of Newfoundland and Great Britain and the Newfoundland Power and Paper Company, a holding company of Armstrong-Whitworth, the builder of the plant (Horwood 1986). In 1926, the mill was sold to the International Power and Paper Corporation of New York (IP). Eric Bowater, later to become chairman of the Bowater Companies, became a director of the Newfoundland Power and Paper Company in 1923, as plans were being made to build the Corner Brook Mill. Bowater Paper Mills Ltd. was organized in

1923 in Great Britain. At the same time, Bowater organized a sales organization to sell Corner Brook paper as its sole agent throughout the world. In 1938, Bowater bought IP's interest in the mill and the name of the International Power and Paper Company of Newfoundland was changed to Bowaters Newfoundland Paper Mills Ltd. Bowaters operated the plant until 1984 when it was sold to Kruger Incorporated of Montreal (Horwood 1986).

Just prior to this, in 1980, an Environmental Assessment Act was passed in Newfoundland. The Minister of Environment has responsibility for administering the Act and can require any activity to be registered, even if not specifically outlined on Schedule 1 of the Act, if he feels there is a potential environmental impact. Whether or not an assessment is required depends upon government review and public screening of the registration.

In late 1981, the Wilderness and Ecological Reserves Advisory Council requested that forestry projects in the Little Grand Lake area be registered under the Environmental Assessment Act because of the importance of the area to pine marten. In January 1982, the Minister of Environment requested that Bowaters register all logging and associated road building activities in the Little Grand lake area under the Environmental Assessment Act. Bowaters subsequently submitted a registration document. Based on a review of the document by representatives of the provincial and federal government and the public, the Minister directed Bowaters to prepare an Environmental Impact Statement for their forest harvesting operations in the Little Grand Lake area. The Minister also established the boundaries of the E.A.A. for the company. In late 1982, Terms of Reference (TOR) for the Environmental Impact Statement were approved by the Minister of Environment following a review by

the Environmental Assessment Committee and the public. The TOR required specific component studies for pine marten and archeology.

Independent of this, the Newfoundland and Labrador Wildlife Division supported an MS study on marten by Joyce Snyder in 1982-84. Bowaters was in the process of selling the Corner Brook plant and little was done about the assessment until the company was sold to Kruger. Negotiations between Kruger (Corner Brook Pulp and Paper Ltd.) and the provincial government resulted in a Cabinet exemption allowing Kruger to cut 100,000 cords of wood in the environmental assessment area. One condition of the exemption order was that annual cutting plans for the exempted area had to be submitted to the Wildlife Division for approval, another required CBPPL to undertake a study in cooperation with the Wildlife Division to determine the impacts of logging on the pine marten. This report is a result of the research we conducted as part of that environmental assessment study funded by Kruger.

The Current Problem

During the last 30 years, timber harvesting in western Newfoundland has extended from the Corner Brook area and has encroached on the PMSA. Corner Brook Pulp and Paper, Limited (CBPPL) currently has access to exemptions within and leases surrounding the PMSA and is cutting that timber. They maintain that without future access to harvesting within the PMSA, the economic viability of the Corner Brook mill is uncertain. The remaining marten habitat within and surrounding the PMSA is rapidly being cut. Approximately 4000 of 133,560 ha of forest is cut annually within the larger pine marten distribution area (Figure 2). This rate will probably increase within the next few years (John, pers. comm. 1985, in Snyder 1985). In 1983,

forest accounted for about 87% of the 140 km^2 study area used by Snyder. Forty-seven percent of the forest area had been cut, 18% was in residual stands ranging from 1-270 ha in size, and 35% was in uncut forest. Clear-cutting has continued in this area since 1983. Roughly 5.3 km^2 of the 561 km^2 of forested area on the E.A.A. has been cut. Although marten are completely protected within the PMSA, their habitat is not. It is unknown how many years are required after clear-cutting for a site to regenerate adequately for marten, but data show that greater than 23 years is needed in Newfoundland (Snyder 1984).

The purpose of this report is to assess how timber cutting affects populations of pine marten and their prey base, and to project the impact that future cutting will have on marten in western Newfoundland.

Information for this report came from field studies conducted at Little Grand Lake from November 1985 through August 1987, from prior field studies conducted in western Newfoundland, and from the published literature. This report has been divided into three sections: Part I (Prey Base), Part II (Marten Dynamics), and Part III (Recommendations).

Goal

The overall purpose of this study was to assess the potential impact of forest harvest operations on pine marten in Western Newfoundland, with special emphasis on the environmental assessment area surrounding Little Grand Lake.

Objectives

In order to achieve our goal, we studied the impact of forest harvesting on small mammals, the principal prey base of marten. We determined and

compared prey abundance and densities before and after forest logging. Additionally, we documented home range characteristics and spatial dynamics of marten pre- and post-impact to determine if any significant changes in spatial use was evident.

Criteria for Timber Harvesting

Timber harvesting for this study was carried out in conjunction with Corner Brook Pulp and Paper, Limited. In meetings and correspondence (letters 29 Apr and 6 June 1986) during 1986, all parties agreed to the following cutting regime. Harvesting would incorporate interspersed clear-cuts resulting in a mosaic of cut and uncut areas. Clear-cuts would not exceed 200 meters in width. Residual stands of at least 15 ha in size or uncut corridors would be incorporated into the cut if the distances across were excessive. Where timber was left because of inaccessibility or low volume yields, residual stands would be at least 15 ha in size. Uncut buffer strips 250 meters wide would be left on both sides of large streams and around larger ponds with 100 meter strips on both sides of small streams and ponds. In addition, corridor areas identified in the long-term cutting plan negotiated as part of the exemption granted to CBPPL by the Newfoundland and Labrador provincial government would not be cut. Finally, all cutting would be confined to the experimental section.

Study area place names used in this report as well as location of experimental and control areas for marten home range dynamics are shown in Figures 1 and 3. Note that the control (uncut forests) and experimental (clear-cut) areas are clearly delineated by a dashed line in Figure 3. No attempt was made to calculate area covered by control and experimental areas.

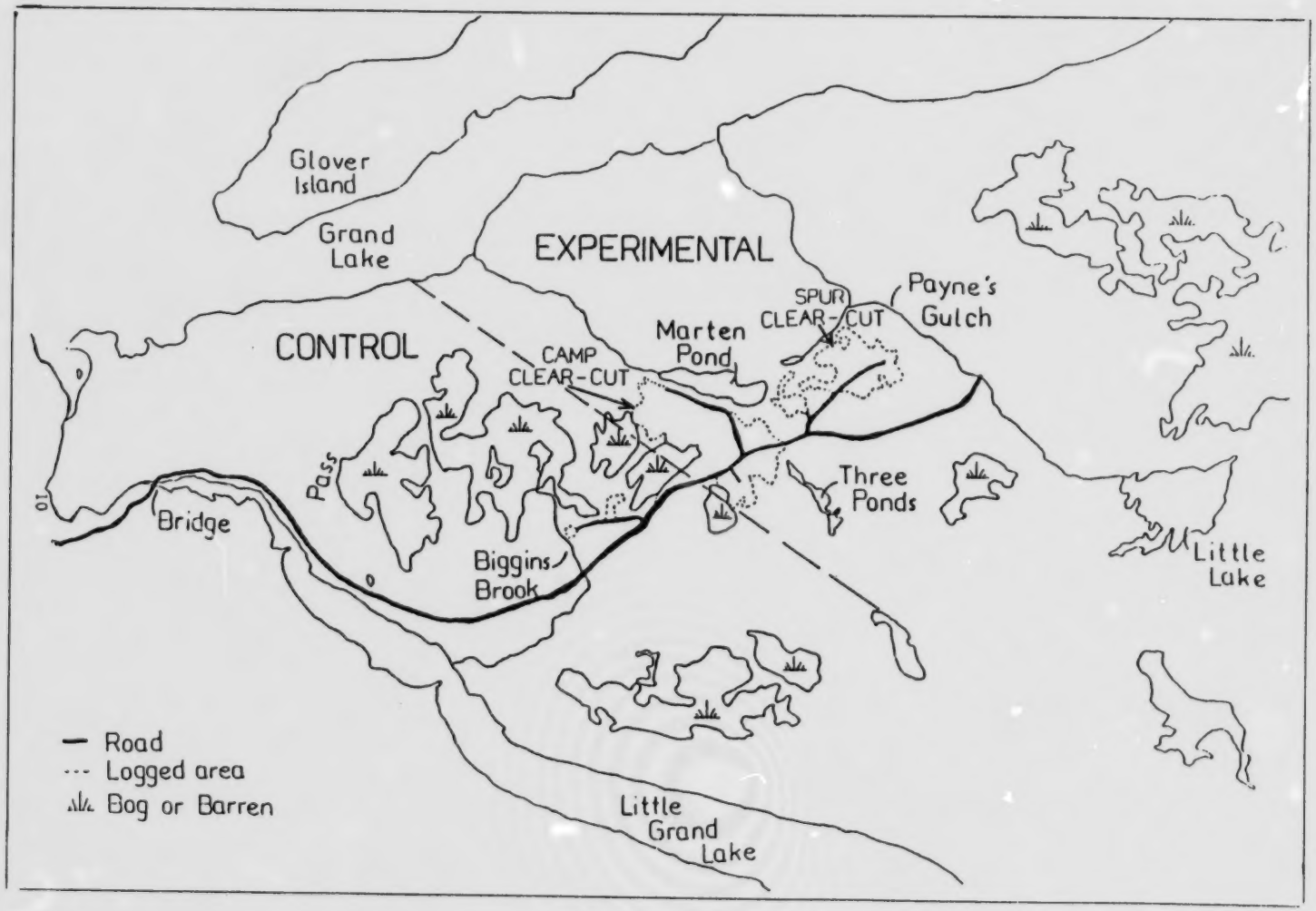


Figure 3. Study area place names.

The key here is whether cutting (treatment) occurred on the area. For the prey base sampling, several undisturbed sites throughout the study area were used as controls. For marten movement dynamics, only home ranges east of the dashed line on Figure 3 were treated as experimental. Logging occurred here. Control home ranges were located west of the dashed line, where no cutting occurred.

Study Area

The study area was located approximately 50 kilometers south of Corner Brook (Figure 1). Old growth forest interspersed with ponds, bogs, and barrens comprised the study area. The first forest harvest treatment occurred during the summer of 1986. The main tree species included balsam fir (Abies balsamea), black spruce (Picea mariana), and white birch (Betula papyrifera). The terrain was rugged with elevations ranging from 120-630 meters. The climate was characterized by relatively cool summers (mean July temperature of 17 C) and moderately cold winters (January mean 6 C). Precipitation was high and evenly distributed throughout the year.

PART I. PREY BASE

In Newfoundland, the depauperate fauna provides a limited prey base for marten. Of the seven small mammal prey species that inhabit the island, only two are endemic: the meadow vole (Microtus pennsylvanicus) and the arctic hare (Lepus arcticus). Snowshoe hare (Lepus americanus), masked shrew (Sorex cinereus), eastern chipmunk (Tamias striatus), and red squirrel (Tamiasciurus hudsonicus) were first introduced in 1864, 1958, 1962, and 1963, respectively (Northcott 1974, Peterson 1966, Northcott et al. 1974, Payne 1976). A single specimen of deer mouse (Peromyscus maniculatus) collected in southwestern Newfoundland in 1968 appears to be the first record of Peromyscus on the island (Gould and Pruitt 1969). Of these seven species, only four are found in any abundance: Microtus, Sorex, Tamiasciurus, and L. americanus. Only meadow voles and masked shrews were abundant in the old growth forests of the PMSA. Tamias are found in moderate numbers locally in the Barachois Pond Provincial Park area and are slowly spreading throughout the western part of the province. L. arcticus are inhabitants of upland barrens while a small population of Peromyscus exists in southwestern Newfoundland. Methods used to determine densities of Sorex and Microtus are given in Appendix I.

RESULTS

The Effects of Logging on Sorex

Average number of Sorex captured in the various habitat types as well as average densities are given in Figures 4 and 5.

1) Comparison of Sorex abundance in Control vs. Experimental areas prior to logging (Spring 1986).

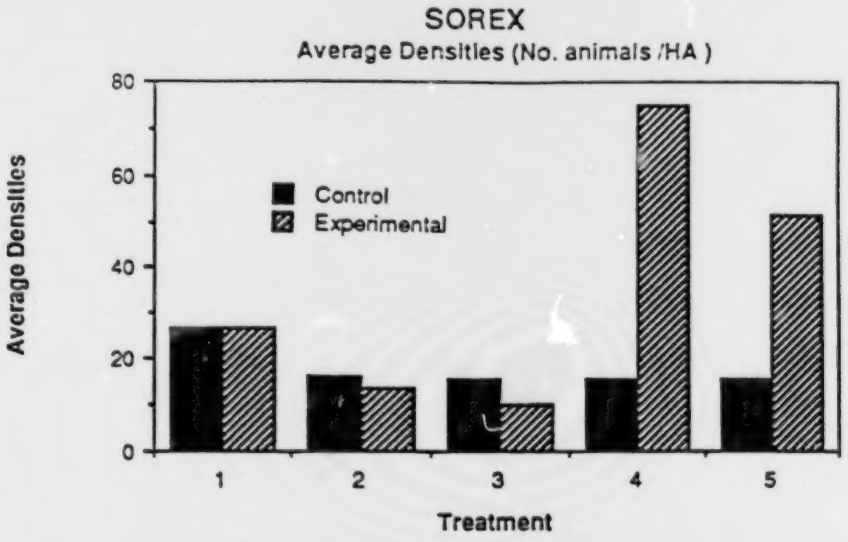
Mean Densities (animals/hectare)	Mean Number Captured
26.6 vs. 26.8	35.3 vs. 43.3

As expected, we detected no significant difference (P=0.05) in Sorex abundance in the control and experimental areas before logging occurred. The areas were similar and no impact had occurred.

2) Comparison of Sorex abundance in Control vs. Experimental areas three-weeks post-logging (Fall 1986).

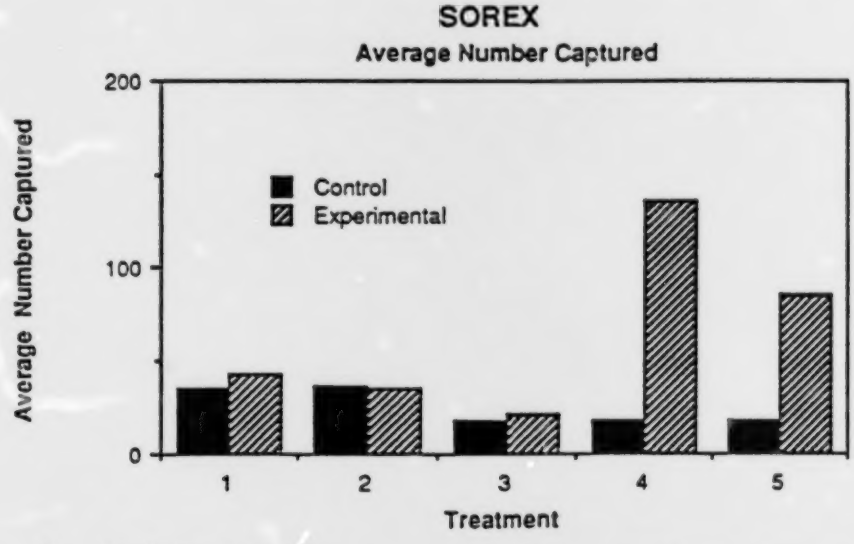
Mean Densities (animals/hectare)	Mean Number Captured
15.9 vs. 13.4	36.0 vs. 35.0

Similarly, no significant difference was found between the abundance of shrews in the mature forest and the area that had just been logged, suggesting that logging had no apparent short term effect on Sorex numbers immediately following timber harvesting. Evidently, insufficient time had elapsed between the time the area was logged and the time we initiated



1- before logging
2- 3-weeks post-logging
3- 1-year post-logging
4- 13-years post-logging
5- 23-years post-logging

Figure 4. Average densities of Sorex in the various habitats.



1- before logging
2- 3-weeks post-logging
3- 1-year post-logging
4- 13-years post-logging
5- 23-years post-logging

Figure 5. Average number of Sorex captured in the various habitats.

trapping (three weeks) for any effects of logging to be detected. Vegetative cover is important to small mammals. The slash left on the ground after logging provided ample cover.

3) Comparison of Sorex abundance in Control vs. Experimental areas one-year post-logging (Spring 1987).

Mean Densities (animals/hectare)	Mean Number Captured
15.7 vs. 10.3	18.0 vs. 21.7

At one-year post-logging, we detected no significant difference in the abundance of shrews between the mature timber and the logged area. A Type II error, i.e., incorrectly concluding there is no effect when one exists, is possible because of the small sample size (three trapping webs). A significant difference between the two habitats could have gone undetected. Sampling three webs per area for two areas (control and experimental) is a formidable effort; irregardless, three replicates per area constitute a small sample.

4) Comparison of Sorex abundance in Control vs. Experimental areas 13-years post-logging (Spring 1987).

Mean Densities (animals/hectare)	Mean Number Captured
15.7 vs. 75.1	18.0 vs. 136.3

A significant difference was found between shrew abundance in the mature timber and 13-year-old cutovers with almost seven times as many Sorex found in the cutover, giving a calculated density of five times greater.

5) Comparison of Sorex abundance in Control vs. Experimental areas 23-years post-logging (Spring 1987).

Mean Densities (animals/hectare)	Mean Number Captured
15.7 vs. 51.3	18.0 vs. 85.7

Sorex were approximately three times more abundant in the precommercially thinned 23-year-old cutover than in the mature uncut timber.

From these data, it appears that regenerating forest stands promoted a significant increase in Sorex numbers over intermediate to long range periods although densities were not significantly different in the short term.

6) Comparison of Sorex abundance between Control areas: Spring 1986 vs. Fall 1986.

Mean Densities (animals/hectare)	Mean Number Captured
26.6 vs. 15.9	35.3 vs. 36.0

Comparison of control areas in the spring and fall of 1986 indicates no significant difference between them. Although calculated shrew density was lower in the fall, the average number of shrews captured was similar. A decline in density from 26.6 to 15.9 per hectare was unusual since we expected an increase in shrew numbers throughout the summer, to the onset of winter. As evidenced by Microtus data presented below, something apparently happened

during the summer of 1986 that not only prevented the Sorex population from increasing, but may have caused the population density to decrease somewhat. A Type II error is possible.

7) Comparison of Sorex abundance between Control areas: Spring 1986 vs. Spring 1987.

Mean Densities (animals/hectare)	Mean Number Captured
26.6 vs. 15.7	35.3 vs. 18.0

No significant difference was detected between the 1986 and 1987 spring controls. Again, the possibility of a Type II error exists due to a small sample size.

8) Comparison of Sorex abundance between Control areas: Fall 1986 vs. Spring 1987.

Mean Densities (animals/hectare)	Mean Number Captured
15.9 vs. 15.7	36.0 vs. 18.0

There was virtually no difference between the density of shrews in the 1986 fall and 1987 spring controls. However, the number of Sorex captured in the fall of 1986 (n=36) was twice that captured in the spring of 1987 (n=18). A Student's t- test indicated no significant difference (P=0.05). However, at an alpha level of 0.15, a significant difference is indicated. Two possibilities are suggested: 1) a Type II error due to the small sample size, and 2) the densities obtained using the trapping web design may be incorrect. Comparisons 6, 7, and 8 suggest a distinct reduction in Sorex numbers even

though differences do not appear significant at P=0.05. Comparison 1 suggests the non-significant differences noted in comparisons 6, 7, and 8 may be biologically significant.

Apparently some factor other than logging influenced the Sorex population between the spring of 1986 and the fall of 1986. We expected an increase in shrew numbers throughout the summer to the onset of winter, yet no increase occurred. If something had not happened to the Sorex population, the density of shrews in the 13-year-old and 23-year-old cutovers may have been much higher than observed. Regardless, regenerating clear-cuts promoted an increase in Sorex numbers. Sorex were three to five times more dense in regenerating clear-cuts than in old growth forests.

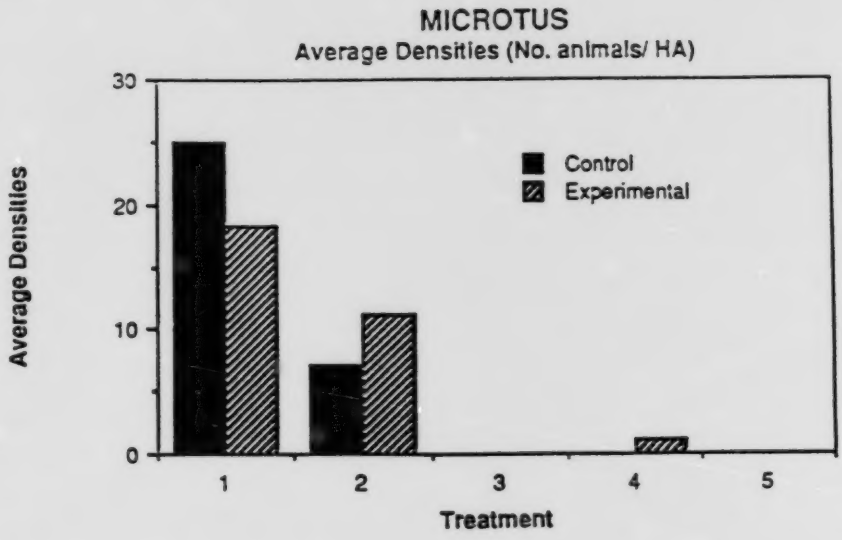
The Effects of Logging on Microtus

The average number of Microtus captured in the various habitats, as well as average densities, are given in Figures 6 and 7.

1) Comparison of Microtus abundance in Control vs. Experimental areas prior to logging (Spring 1986).

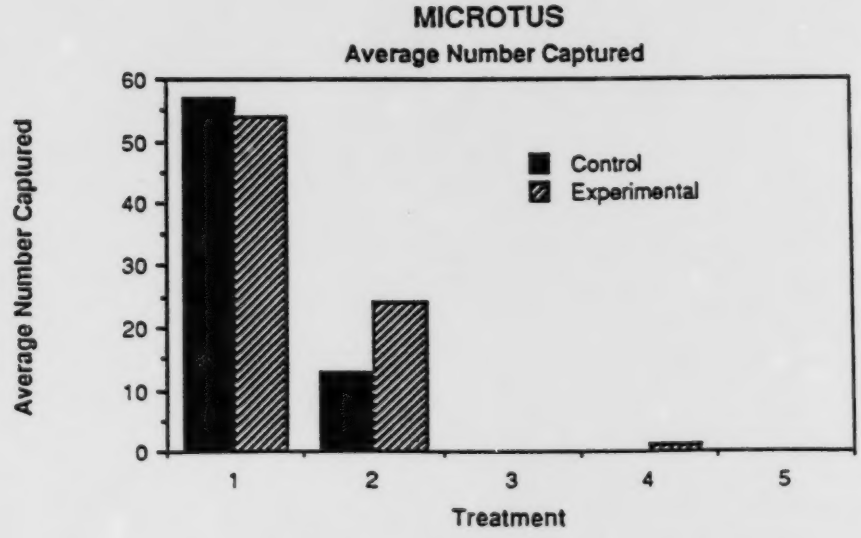
Mean Densities (animals/hectare)	Mean Number Captured
25.0 vs. 18.2	57.0 vs. 54.0

No significant difference in vole abundance was found between the control and experimental areas before logging occurred. Comparison of the average numbers captured in the control (n=57) with the average number captured in the experimental (n=54) further suggests no significant difference between the two



1- before logging
2- 3-weeks post-logging
3- 1-year post-logging
4- 13-years post-logging
5- 23-years post-logging

Figure 6. Average densities of Microtus in the various habitats.



1- before logging
2- 3-weeks post-logging
3- 1-year post-logging
4- 13-years post-logging
5- 23-years post-logging

Figure 7. Average number of Microtus captured in the various habitats.

areas. Again, this is what we would expect before logging since both areas were similar.

2) Comparison of Microtus abundance in Control vs. Experimental areas three-weeks post-logging (October 1986).

Mean Densities (animals/hectare)	Mean Numbers Captured
7.1 vs. 11.2	12.7 vs. 24.3

While there appears to be no significant difference in vole densities between the 1986 fall control (mature timber) and the 1986 fall experimental (cutover immediately following logging), comparison of the average numbers captured shows almost twice the number of voles in the cut area (n=24.3) as in the uncut area (n=12.7). Although no significant difference is indicated here either, it does suggest the possibility of a Type II error.

3) Comparison of Microtus abundance in Control vs. Experimental areas one-year post-logging (Spring 1987).

Mean Densities (animals/hectare)	Mean Number Captured
0.0 vs. 0.0	0.0 vs. 0.0

No voles were captured in the mature forest or the one-year-old cutovers in the spring of 1987. Apparently something caused a drastic reduction in the vole population during the winter.

4) Comparison of Microtus abundance in Control vs. Experimental areas 13-years post-logging (Spring 1987).

Mean Densities (animals/hectare)	Mean Number Captured
0.0 vs. 1.2	0.0 vs. 1.3

No voles were captured in the mature forest and only an average of 1.3 were captured in the 13-year-old cutovers in the spring of 1987.

5) Comparison of Microtus abundance in Control vs. Experimental areas 23-years post-logging (Spring 1987).

Mean Densities (animals/hectare)	Mean Number Captured
0.0 vs. 0.0	0.0 vs. 0.0

No voles were captured in the mature forest or the 23-year-old cutovers in the spring of 1987, further suggesting a serious decline in numbers over the winter months.

6) Comparison of Microtus abundance between Control areas: Spring 1986 vs. Fall 1986.

Mean Densities (animals/hectare)	Mean Number Captured
25.0 vs. 7.1	57.0 vs. 12.7

A comparison of the 1986 spring and fall control densities indicates no significant difference. However, when we compared the average number of voles captured in the spring control ($n=57.0$) to the average number captured in the fall control ($n=12.7$), we obtained a significant difference at $P=0.07$ level.

More than four times the number of Microtus were captured in the spring, indicating a biologically significant difference. The lower number of Microtus captured in the fall is unusual since vole numbers usually increase throughout the summer until the onset of winter.

7) Comparison of Microtus abundance between Control areas: Spring 1986 vs. Spring 1987.

Mean Densities (animals/hectare)	Mean Number Captured
25.0 vs. 0.0	57.0 vs. 0.0

A significant difference was found between the 1986 and 1987 spring controls. It appears that the Microtus population was locally extirpated since none were captured in the spring of 1987. Vole numbers decreased from a density of 25.0 per hectare at the beginning of the study to 0.0 per hectare at the end of the study.

8) Comparison of Microtus abundance between Control areas: Fall 1986 vs. Spring 1987.

Mean Densities (animals/hectare)	Mean Number Captured
7.1 vs. 0.0	12.7 vs. 0.0

A significant difference was found between the 1986 fall and the 1987 spring controls. Vole numbers decreased from a density of 7.1 per hectare in the fall to 0.0 per hectare in the spring. These data support the conclusion that some factor, in addition to or other than logging, was affecting the Microtus population.

During the same period, a disease outbreak of encephalitis (see marten section below) caused heavy marten mortality in the fall of 1986. Although no disease was noted for Microtus, its occurrence is at least remotely possible. We were unable to relate the decline in Microtus numbers to marten mortality or vice versa.

Alternate Prey Species

Some measure of abundance was obtained for several other prey species found within the study area. Although these species are usually secondary in importance as prey, they become more important when microtine numbers are low. Methods used to estimate relative densities and abundances are given in Appendix I.

Tamiasciurus hudsonicus

Red squirrels were commonly seen throughout the study area although not in great abundance. Tracks were seen almost daily during the winter months, and a trapping program in the summer of 1987 resulted in the capture of eight different squirrels on an effective area (see Methods) of 7 ha, giving an estimate of 1.1 squirrels per hectare.

Lepus americanus

A trapping program for snowshoe hare scheduled for winter 1986 was cancelled when it became obvious that hares were virtually non-existent on the study area. Instead, trails seen while travelling throughout the area in winter were counted to give an estimate of hare abundance before and after logging. Before timber harvesting, only 9 trails were seen over a period of 81 days, giving an average of 0.11 trails per day. In the winter of 1987,

after logging, 53 trails were seen over 65 days, yielding an average of 0.82 trails per day, and indicating that snowshoe hare numbers had increased slightly after harvesting. Most of the trails seen in 1987 were along the edge of the recent cutover area with thick regenerating balsam fir close by. Hare were by no means abundant or even common on the immediate study area.

At the beginning of this study, there were no clear-cuts in the immediate study area; therefore, no estimate of snowshoe hare abundance could be determined in regenerating clear-cuts. However, in older clear-cuts outside the study area where vegetative cover was abundant, hare sign was plentiful. No sign of marten was observed in these older clear-cuts during our study.

Peromyscus maniculatus

Until this study, it was not certain whether a breeding population of deer mice existed in Newfoundland. Forty-four deer mice were trapped during our field work, indicating the presence of at least a small population on the west coast of the island (Tucker et al., in press). Only ten mice were captured on the trapping webs, seven of these in the 13-year-old cutover. The rest were trapped in various locations throughout the study area in an attempt to see how widespread the species was in the area.

Tamias striatus

Several chipmunks were seen outside the study area and one was captured in the 23-year-old cutover area. Only one chipmunk was seen inside the study area. None were trapped.

Lepus arcticus

There was no sign of arctic hare within the study area, although they were commonly found on the Buchans Plateau located in barrens just east of the study area.

Scat Analysis

One hundred ninety-four marten scats, collected between November 1985 and August 1987, were analyzed by methods discussed in Appendix I. Of these, only 11 were collected in 1987. Fewer scats were encountered in 1987 for two possible reasons: 1) marten numbers were much reduced, and 2) the study design required that more time be spent in clear-cuts in 1987. Percent composition of marten scats is given in Table 1. Microtus, found in 91.2 percent of the scats, was undoubtedly the most important prey species for marten. Berries were second in importance, occurring in 19.6 percent of the scats. Sorex appeared in 15.5 percent of the scats with other food items occurring less frequently.

Table 1. Composition of marten scats by frequency of occurrence (%).

Food Item	SEASON				
	Spring[1] (n=20)	Summer[2] (n=87)	Fall[3] (n=57)	Winter[4] (n=30)	Total (n=194)
Microtus/Peromyscus	95.0	93.1	100.0	66.7	91.2
Sorex	30.0	5.7	21.1	23.3	15.5
Tamiasciurus	5.0	1.1	——	20.0	4.1
Lepus	——	——	——	3.3	0.5
Birds	5.0	9.2	6.0	10.5	7.2
Berries	5.0	41.4	2.0	——	19.6
Insects	——	5.7	——	——	2.6
Carrion	——	——	3.6	13.3	.1
Unknown	——	1.1	——	13.3	2.6

[1]March 23 - June 20, 1986
[2]June 21 - September 22, 1986
[3]September 23 - December 22, 1986
[4]December 23, 1986 - March 2, 1987

DISCUSSION

In Newfoundland, the depauperate fauna provides a limited prey base for marten. In Labrador, where marten numbers are much higher than in Newfoundland, there are nearly three times as many small mammal species available as prey to marten (Appendix II).

During this study, microtines were the most important prey for marten as measured by frequency of occurrence in scats. Bateman (1982) found that snowshoe hare in Southwest Brook, just south of our study area, were the most important prey item in winter, occurring very abundantly in winter. Meadow voles ranked second in importance. Over the course of this study, Microtus populations declined to almost zero density, apparently independently of logging. Logging may have an effect on vole numbers, but that effect was masked by a drastic reduction in vole numbers during this study. It is well known that many, but not all, Microtus populations fluctuate with a periodicity of 3-4 years (Krebs and Myers 1974, Taitt and Krebs 1985), such that in some years vole numbers are extremely reduced. Microtine cyclicity will not be discussed here, but it appears that Microtus in Newfoundland do fluctuate in population density. We tried to determine whether the decline in Microtus numbers was restricted to the study area. Fifty snap traps were placed 85 kilometers north, 40 kilometers southwest, and 30 kilometers southeast of the area and checked for two nights. No voles were captured, suggesting that the decline was more widespread. Lemon and Phillips (pers. comms., Oct 1987) both noted a reduction in the rodent fauna in Labrador

during the same time period, suggesting a province- and perhaps region-wide decline and cyclicity.

Sorex were found to be the second most important prey for marten during this study, occurring in 15.5 percent of the marten scats. No significant difference (P=0.05) in Sorex abundance was found between the undisturbed forest, the recent cutover, and the one-year-old cutover. However, significant differences in Sorex abundance were found between undisturbed forest and older regenerating cutovers (13- and 23-year-old sites). Sorex densities were three to five times as high in regenerating clear-cuts.

Other prey species occurred less frequently in marten scats collected during this study, indicating they were less important prey. Red squirrels were commonly seen throughout the study area, but occurred in only 4.1 percent of the scats. Snowshoe hare, virtually non-existent in the mature forest of the study area, were found in 0.5 percent of the scats. Hare comprised 58.9 percent of marten diet in southeastern Manitoba at a time when hare numbers were high (Raine 1987). In nearly all other studies, snowshoe hare were found in small to moderate quantities (Marshall 1946, Cowan and Mackay 1950, Quick 1955, Lensink et al. 1955, Weckwerth and Hawley 1962, Soutiere 1978, and Zielinski 1981). Gashwiler (1959) found only a few snowshoe hare in a virgin forest site in west-central Oregon. The first year after logging, neither hares nor their signs were observed in the clear-cut. Observations suggested that hares near the forest edge moved into the clear-cut as soon as cover conditions permitted and resided in patches of suitable cover (Gashwiler 1970).

Until our work, there had been two previous reports of Peromyscus on the island. Gould and Pruitt (1969) collected a single specimen in southwestern

Newfoundland in 1968 and Bateman (1983), working in the same area, collected four deer mice in 1981. We trapped forty-four deer mice, indicating at least a small breeding population on the west coast of the island (Tucker et al., in press). Regardless, relatively few deer mice were caught, and it seems unlikely they formed a major part of marten diets.

Eastern chipmunks were introduced to the island in 1962 but, unlike red squirrels, do not seem to be dispersing throughout the island very quickly. Few observations of chipmunks were made during this study and no sign of chipmunk remains was found in the marten scats.

There was no sign of arctic hare in the study area although they are commonly found in barrens on the Buchans Plateau. Unlike marten, they prefer habitat devoid of spruce and fir; therefore, encounters between the two are probably rare.

Access to the Subnivean Zone

Marten generally hunt in crevices under stumps, fallen logs, and rocks. During winter, objects at ground level are difficult at best for marten to reach when the snowpack is deep, contains ice layers, or is densely compacted. Although marten can dig directly through the snowpack, hunting becomes energetically more costly as snow depths increase. Marten reduce energy costs by using natural crevices around objects protruding from the snow as avenues to the subnivean zone. Much circuitous travelling behavior is directed toward finding access routes to the subnivean zone around tree trunks, rocks, and logs (Hargis 1982). Similar hunting behavior has also been noted in Idaho (Marshall 1942, Koehler et al. 1975), Wyoming (Campbell 1979), Maine (Soutiere 1978), Ontario (Francis and Stephenson 1972), California (Spencer 1981,

Zielinski 1981), and Finland (Pulliainen 1981). During this study, marten were tracked for a total of 12 kilometers, ninety percent of which was in mature forests. On sixteen occasions they travelled under the snow, and in six cases climbed trees. No hunting behavior was observed in cutover areas.

Winter thaws are common in Newfoundland and layers of ice often form in the snow, making it difficult or impossible for marten to reach objects at ground level. Access to the subnivean zone may not be as readily available in cutovers as it is in forested areas with a buildup of coarse woody debris (Koehler and Hornocker 1977, Hargis 1982). With the absence of trees and accumulating snow levels in cutover areas during winter, access to the ground is made much more difficult at a time when availability of prey is especially critical.

Prey Availability

Grakov (1972), Hargis (1982), and Koehler and Hornocker (1977) found that rodents were more accessible to marten in winter beneath the shallower snow depths of windfall-cluttered mature spruce-fir stands, than in open hardwood stands and cutovers where snow depth was greater. In summer, dense plant growth in clear-cuts may reduce marten hunting success by providing increased escape cover for prey (Steventon and Major 1982).

CONCLUSIONS

Marten prefer mature coniferous and mixed forests and are influenced by changes in vegetation structure and prey species caused by timber harvesting. Significant changes in abundance or availability of food often is reflected strongly in marten movement patterns, choice of habitat, and productivity (Lensink et al. 1955). Changes in small mammal species composition may produce pronounced and prolonged effects on marten populations by rendering large tracts of former range unsuitable.

In Newfoundland, logging does not appear to have any significant short term effect on Sorex numbers. We found no differences in density one year after logging. Monthey and Soutiere (1985) found no difference in total small mammal abundance between early and late forest successional stages in Maine. However, de Vos (1957) caught more Sorex cinereus in northern Ontario in an uncut mixed forest area than in the freshly-cut area.

Logging does appear to influence Sorex numbers over the long term. We observed an increase in Sorex numbers in the 13- and 23-year-old cutovers. In conifer forests of north-central Maine, both Monthey (1978) and Monthey and Soutiere (1985) found the total catch of small mammals greater in clear-cuts and partial cuts than in uncut stands. This difference was due to an increase in three species: Sorex cinereus, Microtus pennsylvanicus, and Clethrionomys gapperi.

Sorex weigh only four grams on average. Energetically, they only provide about 5 kcal of energy to marten (Thompson 1986). If shrews are an

important prey item for marten, then, ceteris paribus, we expect marten to use cutover areas more often than they appear to do.

Effects of logging on Microtus in Newfoundland could not be determined directly from this study. However, studies elsewhere suggest that vole numbers increase after forest clear-cutting. In Maine, both Monthey (1978) and Monthey and Soutiere (1985) caught higher numbers of meadow voles in clear-cut softwood stands than in uncut stands. However, this pattern may not hold for insular Newfoundland with its depauperate prey base. With lack of interspecific competition, Microtus appear to be found in a variety of habitats. We were unable to determine densities relative to habitat due to the precipitous crash of the Microtus population. Martell and Radvanyi (1977) and Thompson (1986) found voles to be more abundant in clear-cuts than in mature forests in Ontario.

Should Microtus be more abundant in clear-cuts than in mature forests of Newfoundland, one would expect marten to use clear-cuts more often since voles appear to be their main prey species. Both this study and other studies have indicated that marten prefer to inhabit mature coniferous or mixed forests. The reasons for this preference are not clearly understood, but it seems safe to say that prey abundance above certain threshold densities is not the critical factor. However, prey availability may play a more important role. Although voles and other prey species may be more abundant in logged areas, prey availability may be reduced. The patterns we observed suggest that cover may be important for marten as protection from predators, and in maintaining a thermal balance (Buskirk et al. 1988).

RECOMMENDATIONS FOR FUTURE PREY BASE WORK

1) Our data suggest that Microtus are the primary prey of marten in Newfoundland, at least in times of low hare abundance. Their abundance and availability will directly impact marten population numbers in the absence of other prey species. Therefore, regular and periodic trapping of small mammals, particularly Microtus, should be conducted annually to: a) determine relative abundance, and b) determine if their population fluctuations are predictable. We recommend that trapping grids, possibly a matrix of 7x7 stations spaced 50 meters apart, be used rather than trapping webs, if only differences in small mammal numbers in different forest successional stages are required. Trapping grids allow for a larger number of replications in each habitat and take less time to establish.

2) Marten scats give some indication of food availability and should be collected and analyzed regularly, especially when Microtus numbers are low. We recommend year-round collection. Scats can be stored for later analysis. Since meadow voles appear to be the major prey of marten in the study area, determination of alternate prey choices when voles are low in abundance is important. Although determination of contents by frequency of occurrence gives an assessment of food habits, we recommend that volumetric determination of scat contents be considered. Zielinski (1981) and Buskirk (1983) have suggested that this method provides a better assessment of food habit energetics. However, Taylor (pers. comm.) suggests the volumetric analyses technique may entail unavoidable error.

3) We recommend continuation of marten radio telemetry monitoring in conjunction with the small mammal trapping. Another disease outbreak in marten coincidental with a decline in small mammal numbers could suggest a possible relationship between the two.

PART II. MARTEN DYNAMICS

Marten home range dynamics, movements, and demography were studied on the Little Grand Lake study area. Rugged topography and limited access made ground radio telemetry very difficult and nearly impossible in some sections of the study area. For these reasons, live trapping for marten capture, and relocation by triangulation was limited to approximately a 55 km^2 portion of the study area. Methods used are given in Appendix I.

RESULTS

Woods Operations

Private contractors began road building in the study area in June 1986; clear-cutting by CBPPL began August 4, 1986. Previously agreed-upon guidelines for timber cutting were generally not followed. Guidelines meant to maintain a mosaic of cut and uncut areas were not incorporated into the cutting design. Clear-cut patches were not limited to 200 meters in width, and corridors of residual stands were not incorporated into large cutovers. As a result, harvesting operations resulted in two nearly unbroken clear-cuts approximately 173 ha and 86 ha in size. Therefore, we were unable to address the question of how patchy clear-cuts affect marten. In addition, and perhaps due to a lack of close oversight, clear-cutting and road right-of-ways were extended beyond the experimental area into the control area (Fig. 3). Fortunately, cutting within the control area was limited and did not preclude an effective control. Planned corridors and buffer strips around ponds were left largely intact. Cutting ended November 7, 1986, although wood was trucked from the area for another week. No cutting was done in 1987 except for a small amount of right-of-way cutting in August to facilitate road building.

Marten Captures

Between November 1, 1985 and August 15, 1987, 4126 trap nights resulted in 243 captures of 43 different marten. In addition, two marten were brought to us by CBPPL personnel (one dead and one ill). Table 2 gives sex, year

Table 2. Marten captured at Little Grand Lake, 11/85-8/87.

No.	Name	Sex	Born	1st Capture
13.	Bunny [1, 2]	F	'81	5-29-86
28.	Ern	M	'84	11-1-85
29.	Wes	M	'81	11-1-85
30.	Edgar	M	'84	11-5-85
31.	Gary	M	'84	11-6-85
32.	Joyce	F	'85	11-7-85
33.	Cliff	M	'77	11-7-85
34.	Nika[1]	F	'81	1-22-86
35.	Theresa	F	'85	1-23-86
36.	Slu	F	'85	1-23-86
37.	Brutus	M		1-23-86
38.	Pasadena	F		1-30-86
39.	Elaine	F	'82	2-19-86
40.	Brent	M		2-23-86
41.	Paul	M	'84	2-27-86
42.	Ken	M	'85	5-06-86
43.	Doug	M	'80	5-18-86
44.	Kevin[2]	M		5-19-86
45.	Barbie	F		5-26-86
46.	Jerry	M	'85	6-18-86
47.	Diane[2]	F	[3]	7-09-86
48.	Cheryl	F	'86	7-15-86
49.	Christine	F	'85	7-26-86
50.	Jim	M	'86	7-27-86
51.	Clint	M	'86	7-23-86
52.	Al	M	'86	8-11-86
53.	Fiona	F	'86	9-13-86
54.	Arnie[2]	M	'86	9-15-86
55.	Ashley	F	'86	9-19-86
56.	Found dead	M	'86	9-19-86
57.	Found sick[2]	F	[4]	10-07-86
58.	Misty	F	'86	10-19-86
59.	---	F	'86	10-28-86
60.	---	F	'86	10-30-86
61.	---	M	[4]	11-01-86
62.	Verne	M	'86	11-01-86
63.	Desiree	F	'86	11-05-86
64.	Kirk	M	'86	11-06-86
65.	Jake	M		12-05-86
66.	Alice	F	'86	1-29-87
67.	Tina	F	'86	3-13-87
68.	Vanna	F	[4]	5-23-87
69.	Kim	F	[4]	7-29-87
70.	Elwood	M	'86	7-29-87
71.	Kelly	F	'86	8-04-87

[1]First captured in 1982.
[2]Captured outside the study area.
[3]Probably a kit, no tooth pulled.
[4]Tooth extracted, age confirmation pending.

of birth, and date of initial capture of marten captured during the study. Ten marten were captured only once. Five were captured outside the study area and were never found to cross into the study area (#13, 44, 47, 54, 57). Thirty-five marten were fitted with radio collars. Long term or detailed movement information was obtained for 14 animals. Home range and habitat use findings for 10 marten are presented in this report. Relocation periods for each marten are given in Table 3.

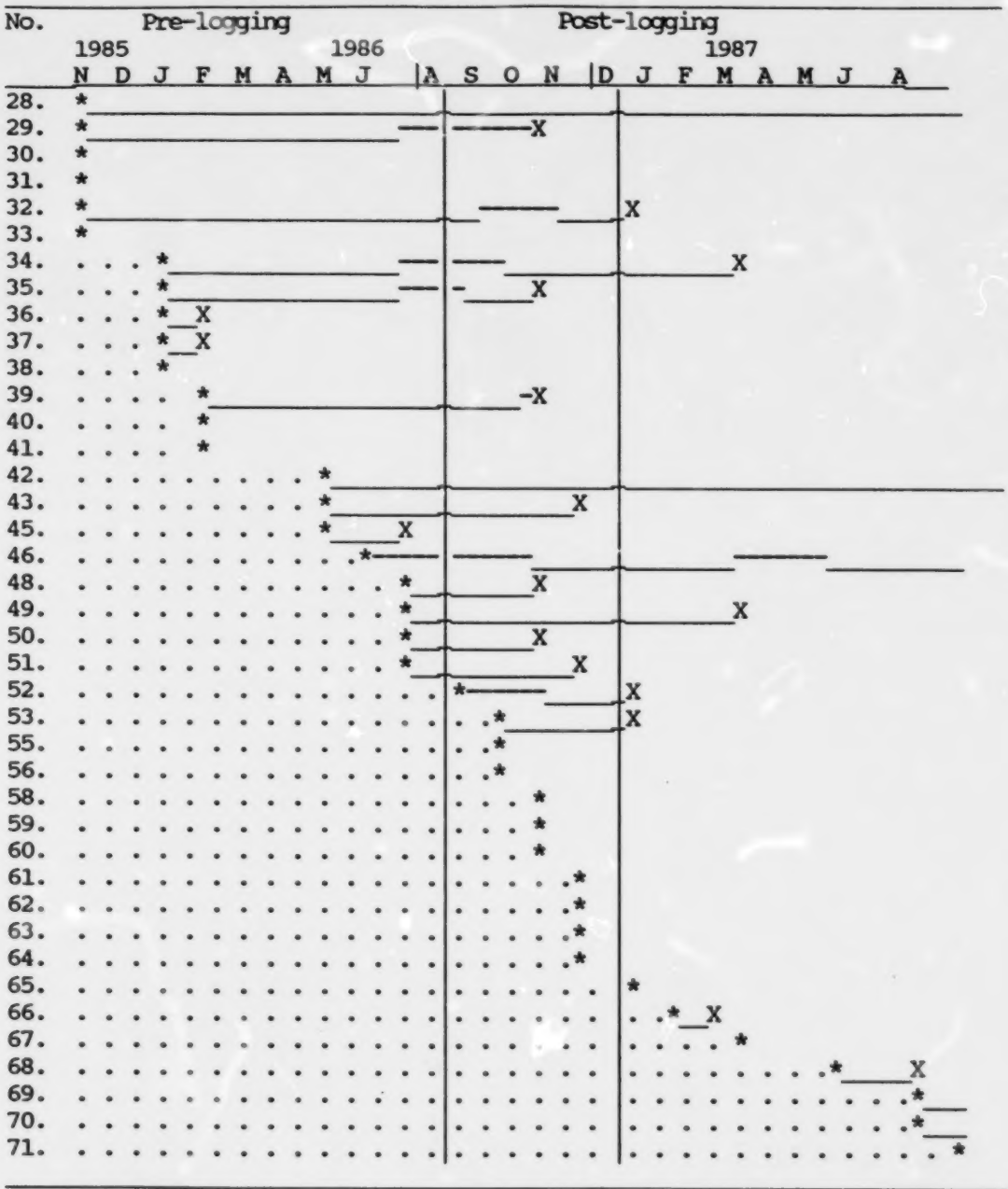
Home Range Dynamics

Marten home range size, core area size, and spatial patterns were dynamic, adjusting to the presence or absence of neighbors, colonization by new marten, the presence of rich food sources during lean times, and the alteration of their habitat by clear-cutting. In addition, the decline of the small mammal prey population likely had an effect. Generally, adult and sub-adult residents maintained home ranges with little or no overlap between neighbors of the same sex, while marten of opposite sexes displayed a high degree of home range overlap. Kits and non-reproductive transients appeared to be tolerated by both resident males and females. Two exceptions to intra-sexual exclusion among residents were documented. During both winters, the presence of a rich food source prompted neighboring marten to intrude into the home range of the resident marten. The second exception occurred during colonization of an area by a new marten.

Effects of camp location

During the winter of 1986, six marten were known to reside on the study area. Five occupied established home ranges; the sixth, marten #35,

Table 3. Time frame for marten captured on study area.



* First capture.
X Died or disappeared from study area.
__ Producing radio signal on study area.
— Present on study area, but uncollared or not producing signal.

was a young transient without a stable home range. However, five marten were conspicuous in their use of the area around the researchers' camp. Carelessly discarded food scraps around the camp provided a comparatively rich food source and affected the movements of each of the marten except #39. Even though camp was well within the home range of marten #29, a neighboring male, marten #28, was frequently located at camp throughout the winter. Although the area around camp was disjunct from marten #28's home range, the area was heavily used and became his center of activity. Camp was also included within the home range of female marten #34. She was first captured in this area in 1982, and had probably been resident since then. However, martens #32 and #35 were also quite conspicuous in their use of the area around camp. Marten #35 was born the previous spring and was not yet one year old. During the winter she was found most frequently near camp, rarely straying far. With the onset of spring she left camp and subsequently used a larger area. Female #32 was found occasionally at camp, although the boundary of her normal home range was six kilometers away. She managed to maintain a stable home range although she was less than one year old. Only marten #39, a reproductively active female, appeared to be unaffected by the presence of camp. By mid-April 1986, snow melt was well underway, and marten were no longer observed at camp. Alternate methods of waste disposal were practiced at camp beginning in spring.

None of the camp relocations obtained between January 15, 1986 and April 15, 1986 for marten #28, #32, and #35 were used in home range calculations, since they resulted from an artificial availability of food. The resulting winter home ranges for marten #28 and marten #32 very closely approximated their summer 1986 home ranges when camp had no effect on their movements. Female #35 became a transient in the spring. Since camp was included within

the normal winter home ranges of marten #34 and #29, camp locations were selectively deleted from calculations of their home ranges using the following criterion: after once located at camp, subsequent camp relocations were not included in home range calculations until the animals had spent at least one day away from camp.

Summary of home range dynamics

Home range relocation data for ten marten on the control and experimental areas were grouped into three treatments of home range use before, during and after logging. On the control area, two females and three males established home ranges. Both females occupied their home ranges until late 1986. Neither appeared affected by the logging operations. Of the males, all were present before logging and continued to use their traditional home ranges throughout the study. One expanded his range into the experimental area upon the death of an experimental marten. None appeared affected by logging operations.

On the experimental area, home range information was obtained for two females, two male kits, and one adult male. One female changed her activity pattern shortly before or concurrent with logging, the other shortly after logging. Their movements showed strong avoidance of clear-cut areas. The two male kits expanded their range through the summer and fall of 1986 before dispersing in the fall. Contact was lost with the remaining adult male just prior to cutting operations began; he subsequently died late in 1986. Details are given below.

Pre- and post-logging comparisons

Comparisons of home range use by ten marten on control and experimental areas before, during, and after logging were made to identify the impacts of logging on resident marten. Data collected from January 15-August 3, 1986 comprised the pre-impact treatment. Logging operations began August 4, 1986 and continued through November 14, 1986; data collected between these dates comprised the "during" treatment. Post-impact data was collected from November 14, 1986 through August 17, 1987.

The impacts of logging on marten are reflected in the movements of the affected animals in various ways. Changes in home range and core area sizes may be noticed. The locations of home ranges and core areas may shift, and changes in the spacing between adjacent animals may be altered. Clear-cut areas within a home range may receive differential use. In extreme cases, an animal whose home range was heavily impacted may abandon its former range.

Pre-impact home range dynamics

Detailed home range information was obtained for six resident marten before logging. Home ranges for females #32, #39, and #34 before logging are shown in Figure 8; similarly, home ranges for males #28, #29, and #42 are shown in Figure 9. Females #32 and #39 represent control females; #34, experimental. Similarly, #28 and #42 were control males, while #29 was experimental. Female #34's home range and core area during this time was centered around the Three Ponds area. The northwest portion of her range lies within the area that was later cut. Relocations for #34 during the period were obtained from January 21-June 20, 1986; her radio collar was non-functional after June 20. Relocations for #32 and #39 were obtained

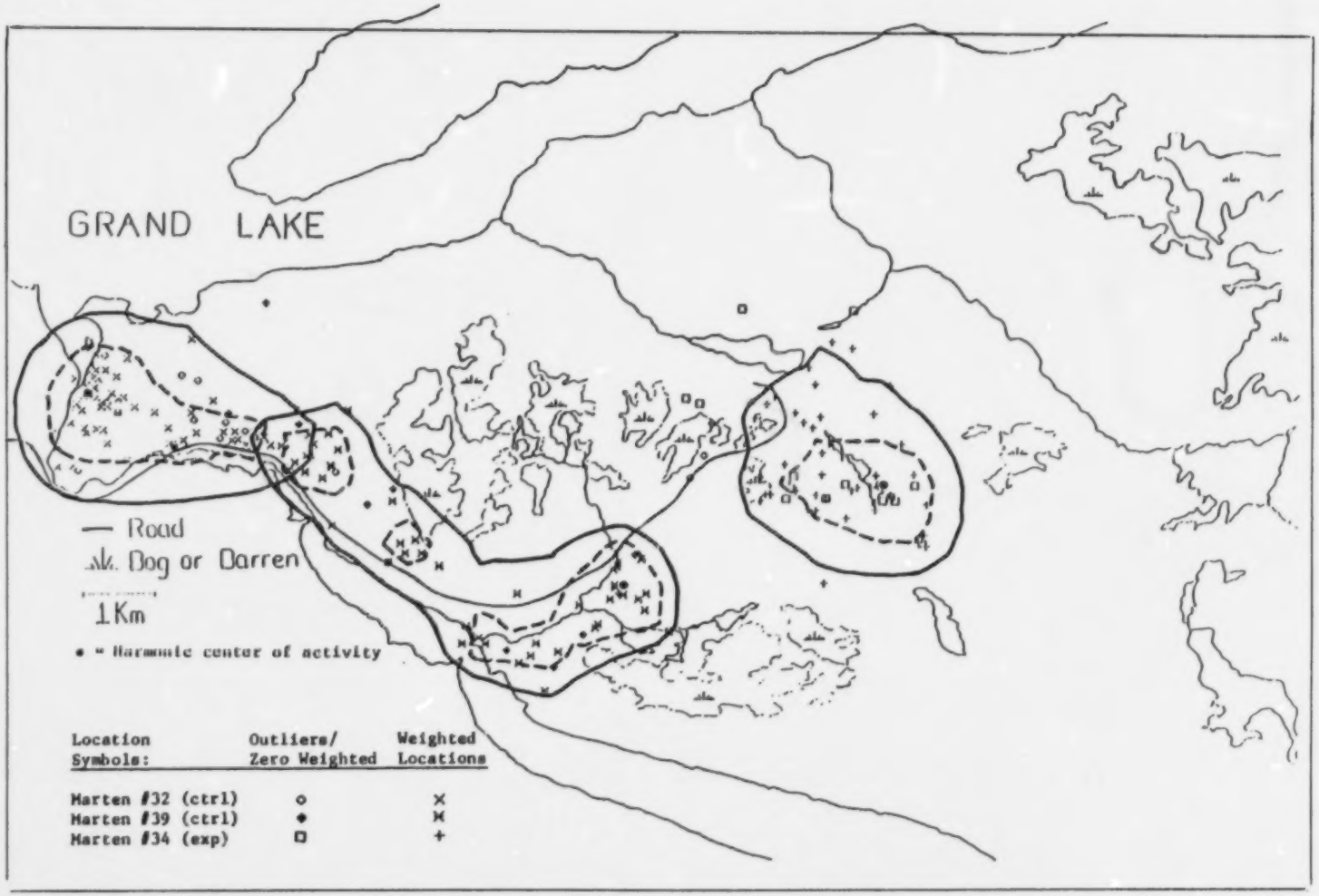


Figure 8. Home ranges (solid lines), core areas (broken lines), and outlier locations for female marten 32, 39, and 34 before logging.

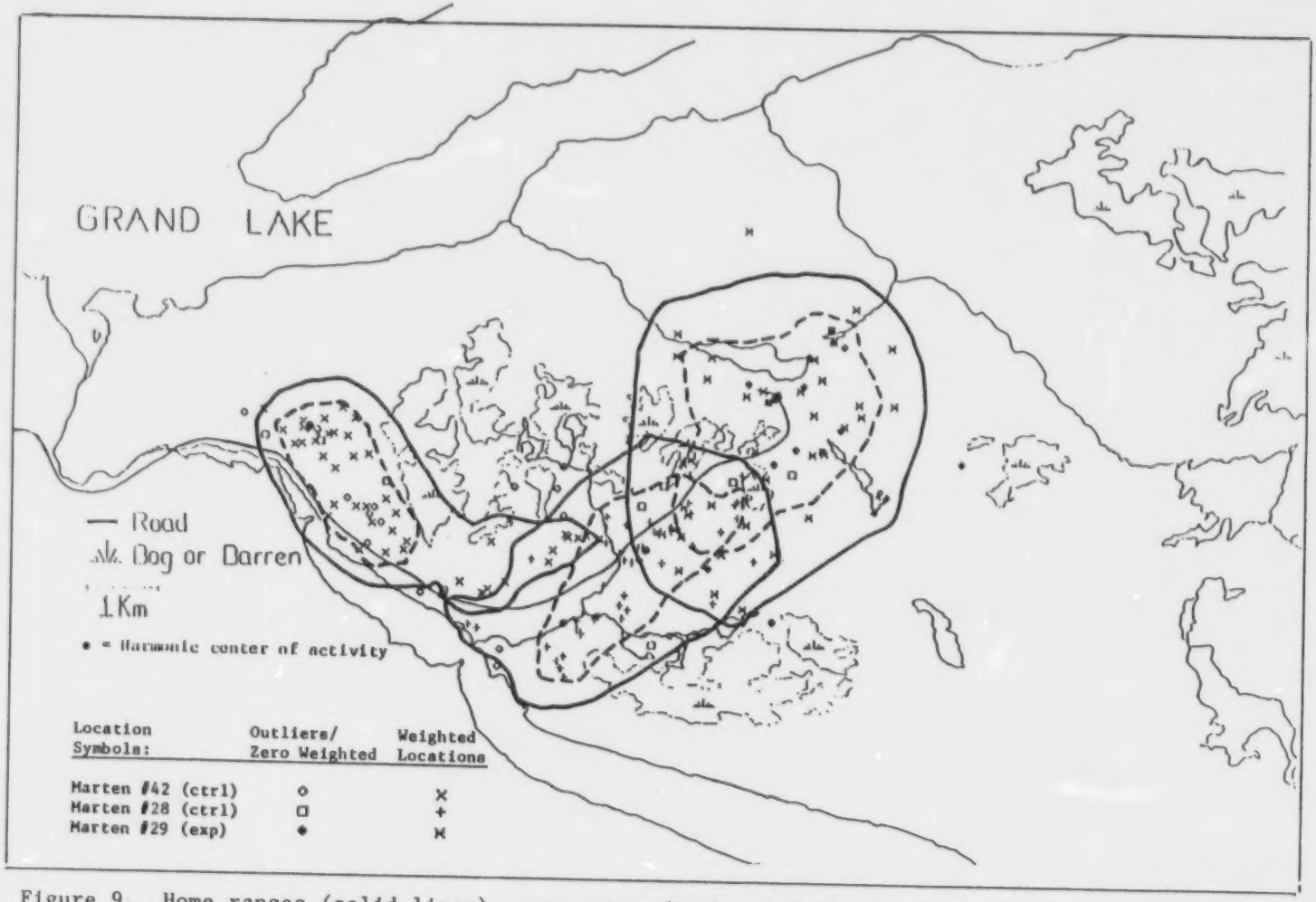


Figure 9. Home ranges (solid lines), core areas (broken lines), and outlier locations for male marten 42, 28, and 29 before logging.

throughout the period from February to August, though relatively few were obtained in the winter months.

Most of the area eventually logged was within male #29's home range (Figure 9). Relocations for him were obtained from January 17-June 19, 1986; after this his collar was non-functional. However, he was captured at camp August 17, 1986 and was seen again at camp October 17, 1986. Marten #29 was recollared upon recapture at camp August 17,1986; however, the only collar available at the time was a used collar with little battery life left and poor signal strength. Upon release we received a signal only once. During the summer and early fall 1986, long delays in obtaining new and refurbished radio collars resulted in some captured marten being released uncollared and prevented the replacement of weak and non-functional collars on other marten. During winter and spring 1986, the home ranges of #29 and #28 overlapped considerably. The high home range overlap with #29 during winter 1986 suggests that #28 may have colonized his range as recently as fall 1985. Number 42 probably began colonizing the area immediately west of #28's range during the spring. During this time, #42 was frequently found within #28's home range. During the winter months, #28 was occasionally found within what would become #42's range, but #42 was probably not yet present.

Thirteen additional marten were captured on the study area during this period. Seven were young transients, three were offspring of females #34 and #39, two were yearlings apparently colonizing portions of the study area, and one was an adult resident of the south shore area of Grand Lake.

Home range dynamics during logging operations

Home ranges for three female marten and four males during logging are shown in Figures 10 and 11, respectively. Three female marten, #34, #39, and #49, were present during logging; only one, #39, was a control. Radio locations were limited to approximately 1-1/2 months during the logging phase for #34 and #39. Numbers 49 and 34 were affected by the clear-cuts. Home ranges were obtained for four male marten, #28, #42, #50, and #51, during logging. Males #28 and #42 were controls occupying home ranges outside the logged area. Males #50 and #51 were captured on the experimental area shortly before logging operations began; both were kits and thought to be offspring of female #34. Clear-cutting occurred within the home ranges of males #50 and #51. In addition, male #29 continued to occupy the experimental area until his probable death in October 1986, although his radio collar was non-functional during this time.

Female #34 was recaptured and recollared September 14, 1986; following this, it became apparent that she had dramatically shifted her home range between late June and mid-September, 1986 (Figure 10). She no longer used the Three Ponds area, her former core area, but shifted to the area just north of her former home range. Two of her kits were captured north of Marten Pond in late July. Their intensive use of this area during August suggests that this was part of their maternal range. The kits' presence in late July suggests an earlier presence by their mother. We could not determine directly whether road building in late June and July influenced her movements.

During this period, #49 occupied #34's former home range centered on the Three Ponds area. Female #49 was first captured and radio collared July 26, 1986; at this time she was a yearling and probably had not been in the area

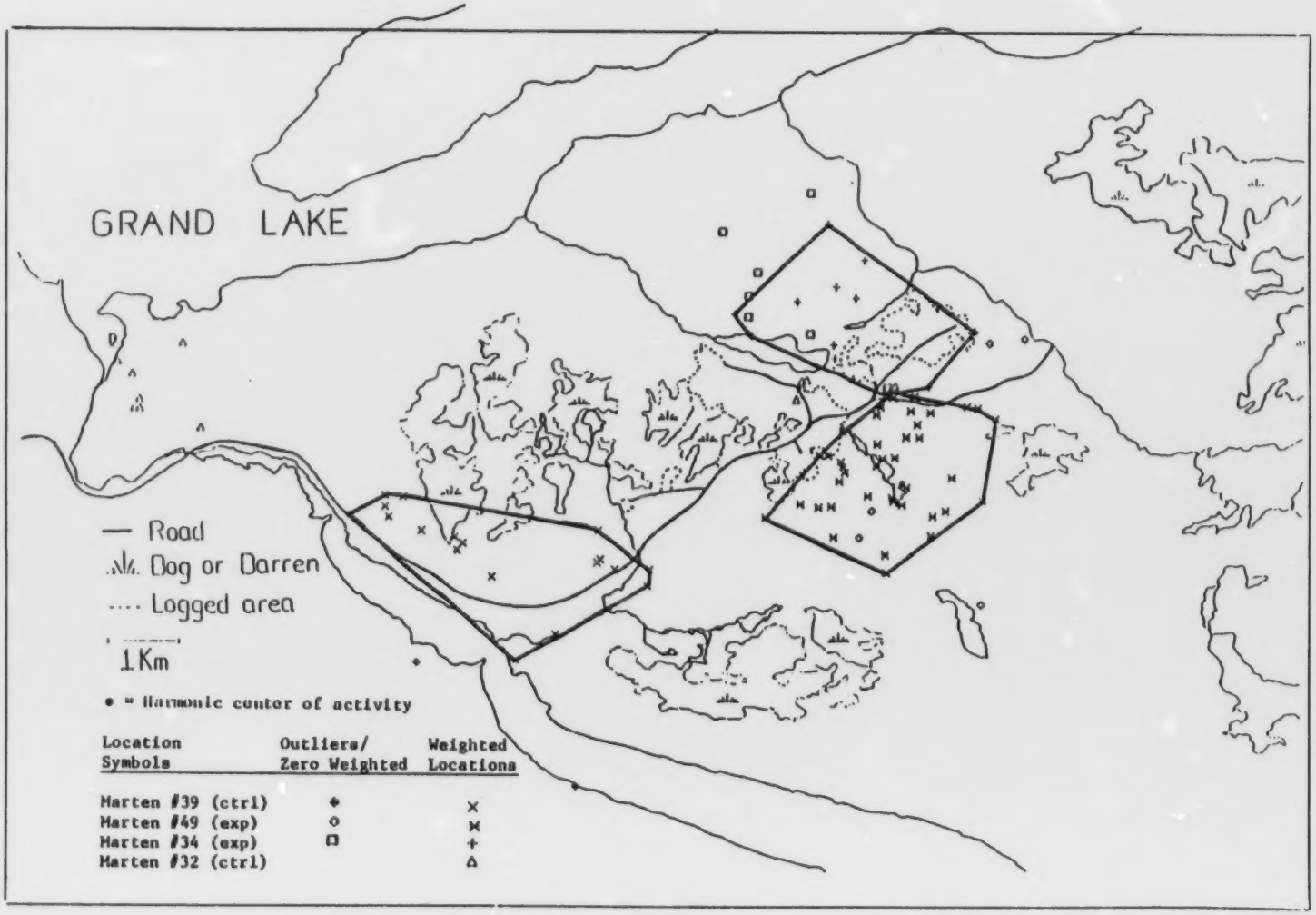


Figure 10. Home ranges (solid lines), and outlier locations for female marten 39, 49, and 34 and locations for female marten 32 during logging.

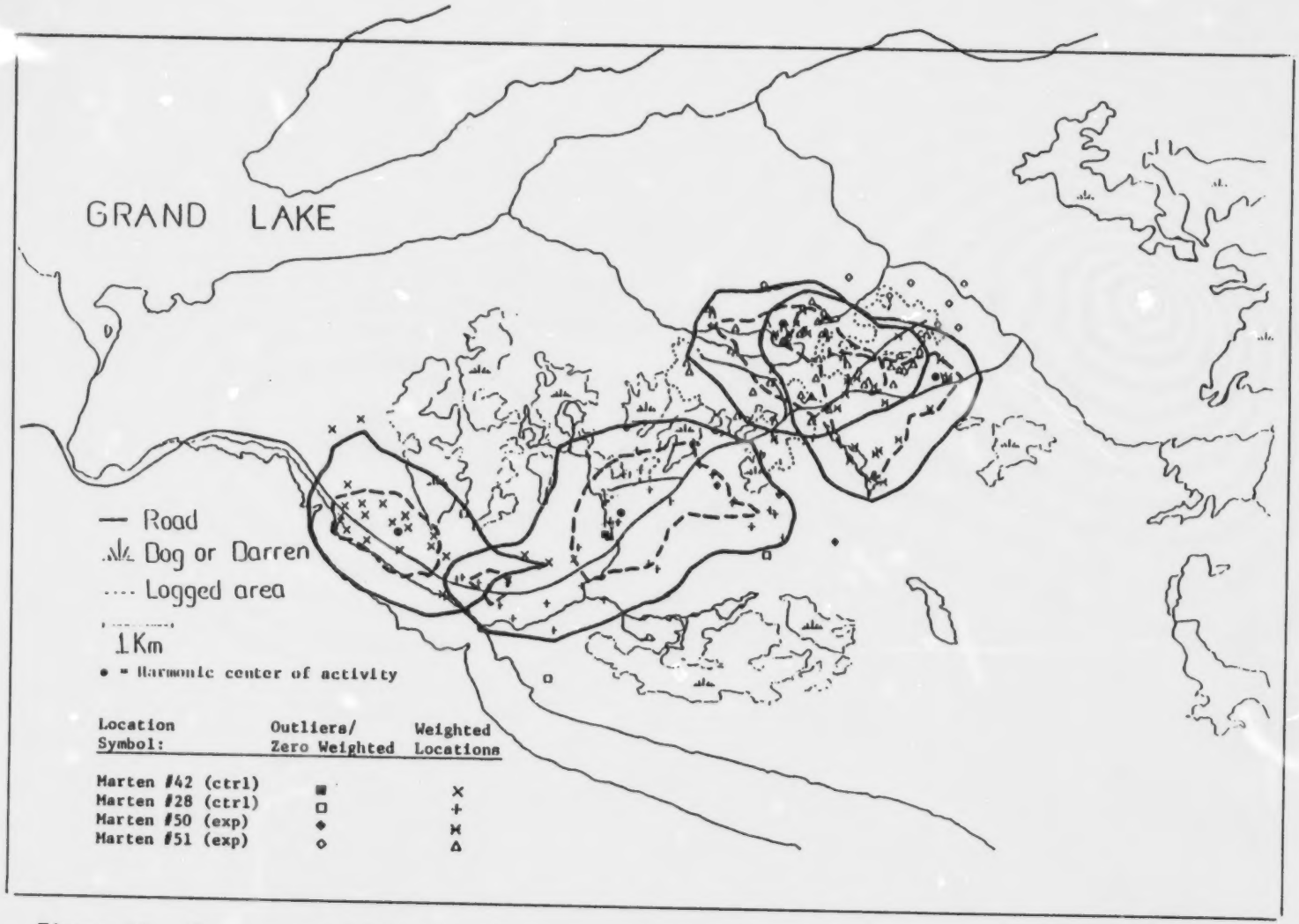


Figure 11. Home ranges (solid lines), core areas (broken lines), and outlier locations for male marten 42, 28, 50, and 51 during logging.

for very long. This further suggests a pre-logging home range shift by #34 since within-sex home ranges in marten do not overlap greatly. Female #39 continued to use approximately the same area until mid-September, when she may have crossed to the south side of Little Grand Lake. We were unable to get many locations on her at this time. She was found dead on the south side of Little Grand Lake October 8, 1986.

Female #32's radio collar ceased functioning in mid-August. She was recaptured October 18, 1986, but not recollared because the fur under the collar was worn and the skin on the back of her neck irritated. She was held at camp for seven days, antibiotic shots administered to prevent infection, and released. On December 1, 1986 she was recaptured and recollared. By this time, her neck had healed and the fur regrown. However, she slipped her collar in early January 1987 and was not observed again. She probably continued to use her usual range at the western end of the study area into the fall, but spent much of November in the camp area (Figure 10). Harmonic mean home ranges were not calculated for #34 and #39 during logging due to insufficient numbers of relocations; convex polygon home ranges are used in Figure 10. Home range and core area sizes are listed in Table 4.

Males #28 and #42 occupied home ranges largely outside of the logged area during the cut; marten #50 and #51 were captured on the experimental area in late July, shortly before cutting operations began (Figure 11). Although a small amount of cutting extended into the home range of #28, it was not enough to preclude him as a control. Both #50 and #51 were thought to be the kits of female #34, born in the spring. Shortly after capture, these marten appeared to confine their movements to the area immediately north and west of Marten Pond. However, as the season progressed they expanded their ranges to that

Table 4. Minimum convex polygon and harmonic mean estimates (see Appendix I for description) of home range and core area size before, during, and after logging at Little Grand Lake.

	Before	During[1]	After[2]	
#34	6.14[2] (93)[3]	—	4.59 (62)	1.87[4]
	1.87[4]	—	1.77	
	4.93[5] (75)	3.19 (16)	3.53 (47)	
#49	—	6.84 (47)	7.81 (30)	
	—	2.35	1.71	
	—	4.21 (42)	8.33 (23)	
#39	8.22 (59)	—	—	
	3.00	—	—	
	8.31 (46)	4.34 (18)	—	
#32	5.34 (88)	—	—	
	2.45	—	—	
	4.24 (67)	—	—	
#28	9.24 (63)	7.96 (44)	18.81 (169)	
	3.82	2.60	6.24	
	8.45 (52)	6.96 (40)	17.11 (135)	
#29	13.16 (83)	—	—	
	5.38	—	—	
	9.88 (50)	—	—	
#50	—	4.57 (35)	—	
	—	2.05	—	
	—	3.75 (30)	—	
#51	—	2.88 (61)	—	
	—	1.18	—	
	—	1.96 (48)	—	
#42	5.18 (64)	2.91 (31)	4.53 (96)	
	2.20	1.16	2.24	
	4.26 (46)	3.08 (29)	3.65 (76)	
#46	—	—	4.01 (96)	
	—	—	2.13	
	—	—	3.58 (91)	

[1]Clear-cut areas were subtracted from these home range estimates.
[2]95% harmonic mean home range size in km^2.
[3]Number of relocations used in home range estimation.
[4]Harmonic core area size in km^2.
[5]100% minimum convex polygon home range size in km^2.

shown in Figure 11. The high degree of overlap between their home ranges and core areas reflects their relationship as siblings. They were frequently located together and often seemed to be following one another. Marten #50 dispersed from the study area in October; #51 in November. Both occasionally passed through clear-cuts. Marten #51 was twice observed foraging in tiny clumps of small uncut trees within a clear-cut. Male kits #50 and #51 were located within clear-cuts two and nine times, respectively, a total of eleven times before disappearing.

Males #42 and #28 continued to use the same areas as previously. However, after #29 disappeared on October 17, 1986, #28 began to colonize #29's range. Home range sizes for males #42 and #28 were probably under-represented during this period. During the fall, #46 (a yearling) was radio collared; he had been trapped in female #32's range three times since June. Eleven new marten (#'s 52, 53, 54, 55, 56, 57, 58, 59, 60, 61, 62) were captured on the study area during logging operations, at least ten of these were dispersing kits. Ten marten also died on the study area during the fall; these mortalities and others will be discussed later.

Post-impact home range dynamics

After logging was completed on the experimental area, we documented sufficient relocations to determine home ranges for two females (#34 and #49) and three males (#28, #42, and #46). Both females occupied home ranges impacted to some degree by cutting operations; two of the three males (#42 and #46) were in the control area; #28 used both the control and experimental areas. Female #34 continued to use the same area as she did during logging until her death in March 1987. Female #49 shifted her home range eastward after logging and then disappeared in May 1987. Males #42 and #46 continued

to use the same ranges used during logging. Male #28 expanded his range to include much of the experimental area in addition to his former range.

After logging, female #34 continued to use the area immediately north and east of Marten Pond until her death March 31, 1987 (Figure 12). Much of the spur clear-cut was included within her range; however, she was rarely located within the clear-cut.

The appearance of female #49 in the Three Ponds area in late July 1986 probably occurred as #34 left the area. During winter 1987, #49 made scant use of the Three Ponds area, shifting most of her use to the area east of her summer-fall 1986 home range. A small part of her summer-fall home range was cut, and the roads going through her range did receive heavy vehicular use.

Male #28 continued to expand his range until it included all of what was known to be #29's former home range plus all of his own range (Figure 13). During 1987, #28's home range included all of the camp and spur clear-cuts. Despite this, he was located only three times of 169 relocations in clear-cuts. His movements were almost totally confined to the forest. However, he was often located near the edges of the clear-cuts. Male #42 continued to occupy the area immediately west of #28's home range, though he no longer went as far east as Biggins Brook.

Males #28 and #42 showed no home range overlap in 1987. Male #46 continued to use the western most part of the study area, with essentially no home range overlap with #42 except for a brief period during February 1987. During this time, #42 found a caribou carcass well within #46's home range and fed on it for four consecutive days despite #46's presence at the carcass.

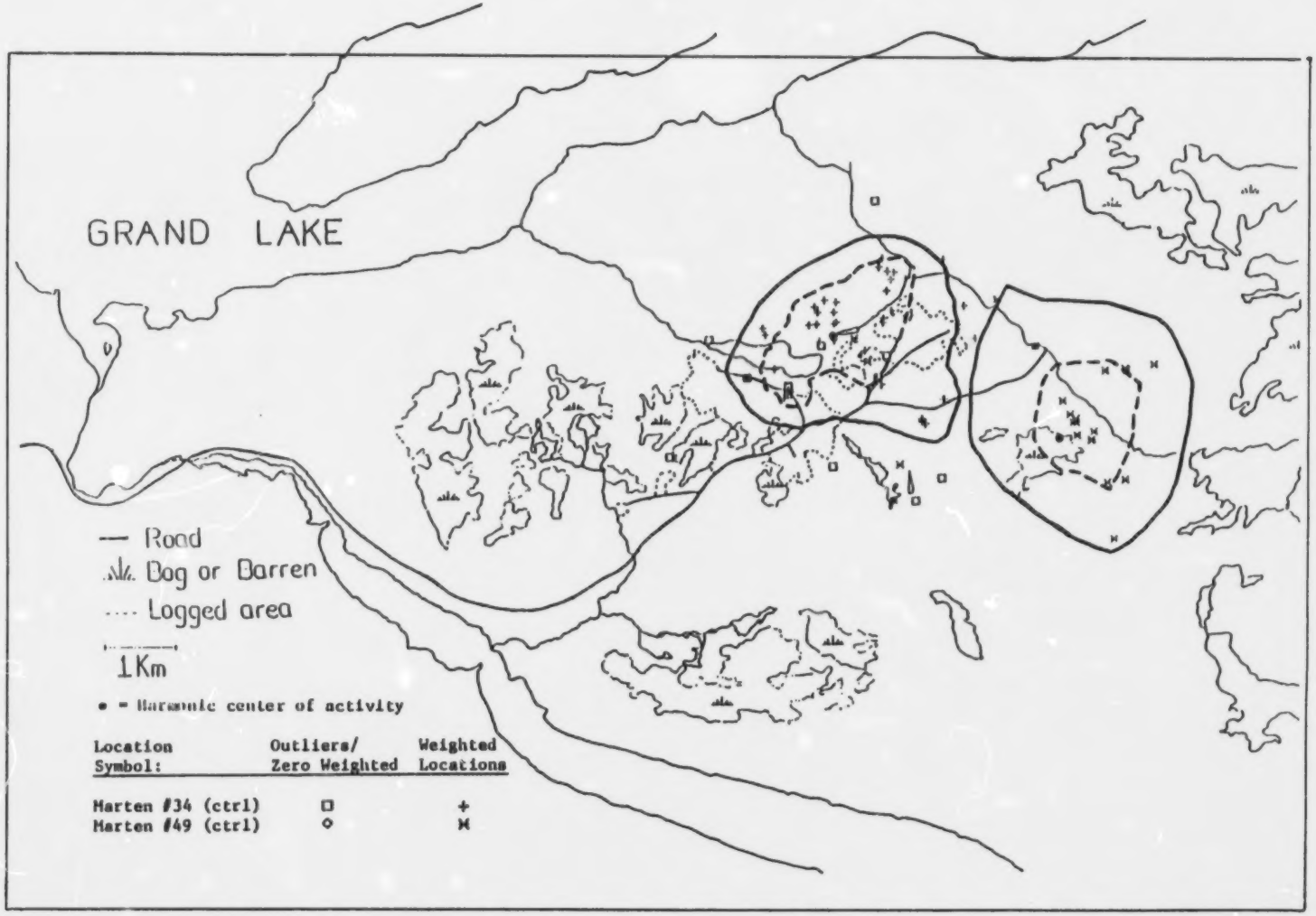


Figure 12. Home ranges (solid lines), core areas (broken lines), and outlier locations for female marten 34 and 49 after logging.

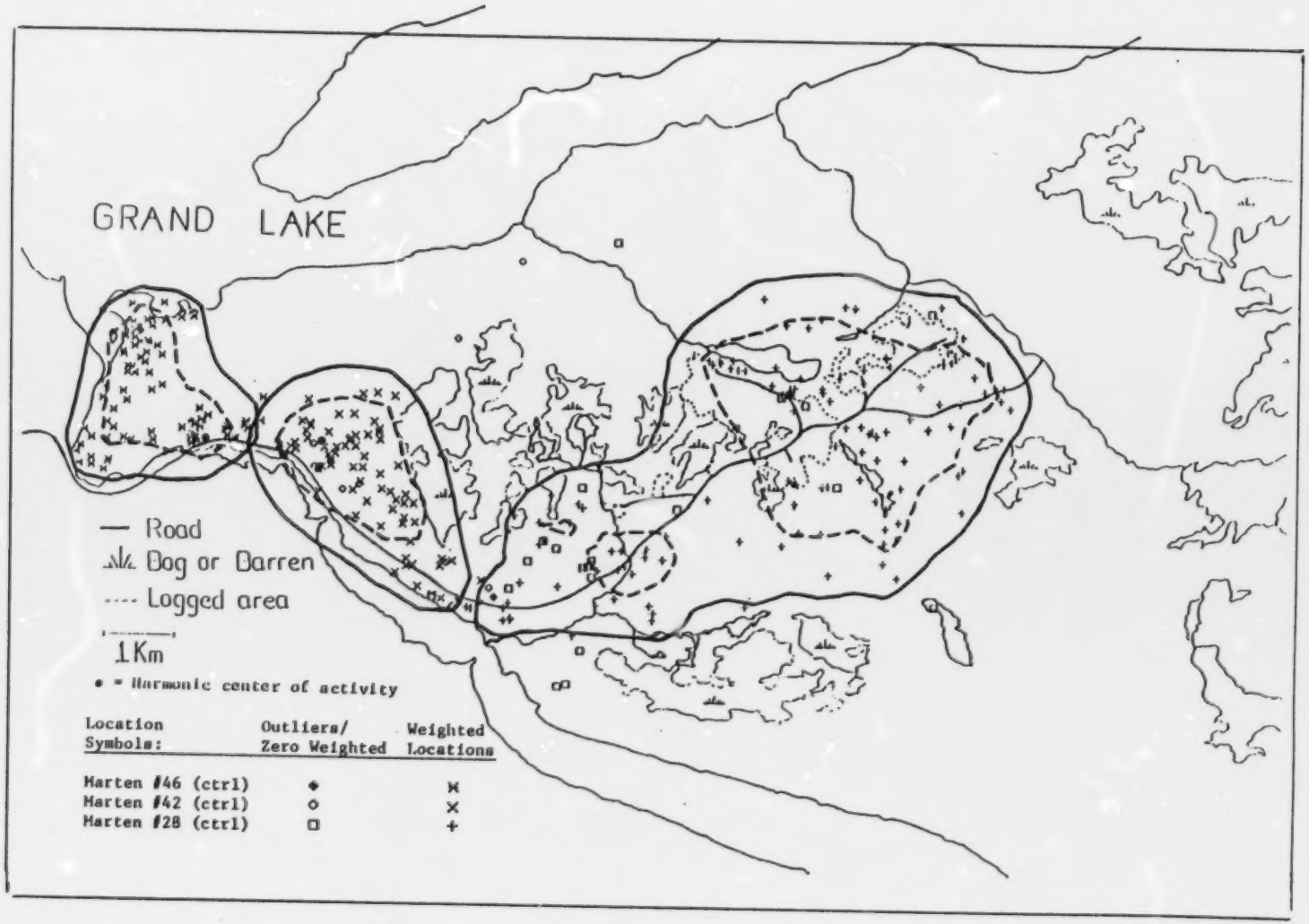


Figure 13. Home ranges (solid lines), core areas (broken lines), and outlier locations for male marten 46, 42, and 28 after logging.

Changes in home range size

Marten #34 and #28 showed changes in home range size after logging (Table 4). The effective home range (see Appendix 1) of #34 after logging was 25 percent smaller than before logging. Her core area remained about the same size. Parts of both clear-cuts were within her home range after logging; it appears that the clear-cuts limited her access to areas of suitable habitat beyond her core area. The home range size and core area size of male #28 doubled after logging to include areas that were cut. We were unable to determine the relative effects of cutting, the availability of unoccupied habitat, and a reduced prey population.

Effects of logging on experimental marten

Marten in the experimental area were rarely found within clear-cuts. Male #51, a kit, was twice seen foraging within groups of tiny tree clumps in recent cutovers during October 1986. Male kits #50 and #51 were located within clear-cuts two and nine times, respectively, during fall 1986. In total, #50 and #51 were located within clear-cuts 11 out of 96 locations or 11.5% of the time. This was probably due to inexperience; they were born in the spring and were still learning how and where to forage. Older marten were found within clear-cuts seven out of 324 locations or 2.2% of the time. Tracks of marten #63 were followed across a small section of clear-cut in November 1986. In January, the tracks of a marten were followed into the spur clear-cut. They left the forest and headed straight for the piles of eight foot long pulp logs stacked along the road. The marten inspected the wood piles briefly. The logs were not yet completely covered with snow. The animal then headed for the forest across the clear-cut. This is the only time we found evidence of a marten crossing an opening larger than 200 meters in

width without using a series of tree clumps to make the crossing. In March, #34 was observed crossing the spur clear-cut. She used a series of tree clumps to make her way across, running through open stretches between the clumps. The widest open stretch crossed was less than 200 meters. Her tracks were also observed in a 200-meter section of the camp clear-cut; again, she used a series of small tree clumps to make the crossing. Female #34 occasionally used a subnivean resting site late in the winter that was approximately 30 meters from the forest edge in a clear-cut. This may have been a den traditionally used before the area was logged. In May, 1987, #28 was observed crossing a clear-cut, travelling from camp to the uncut forest. These are the only instances of marten being found within clear-cuts on the experimental area over a one-year period. On several occasions during winter 1987 when marten tracks were followed, we observed tracks along the edge of clear-cuts but never more than 10 meters inside the clear-cut. We rarely observed marten crossing any large openings. Marten observed crossing roads usually ran across them. On three occasions we observed marten tracks following our snowmobile trails through open areas; in each case the uncut forest was less than 20 meters away.

Throughout the study, we were sometimes unable to locate a specific marten during a telemetry location attempt. From time to time marten went into areas where they could not be located by normal ground telemetry; some animals were more difficult to locate than others. Portions of some home ranges may not have been documented for this reason. Weak signals from transmitters occasionally made individuals difficult to relocate. Furthermore, small sample sizes for some animals during some seasons likely resulted in underestimation of their home ranges. Autocorrelation within a

few data sets, particularly those from the winter seasons, may also have caused underestimation of some home range sizes. For these reasons, home ranges presented here very likely represent minimum values.

Dispersal

We defined dispersal as a permanent move from the natal home range. Transient marten encountered in this study were less than two years old and probably in the process of dispersing. Kits left their natal home range from September through December. All known kits born on the study area either dispersed or died during their first fall. Establishment of a permanent home range began in the second year of life for marten #42, #46, and #49, but apparently began at six months of age or earlier for #32. She was a kit when first captured in November 1985, and maintained fidelity to her home range. No marten older than two years were encountered as transients or dispersers. The fate of most dispersers we encountered is not known.

Long distance dispersal was documented for five animals in this study. Marten #31 and #30, both born in 1984, were captured and fitted with radio collars on the study area in November 1985. Male #31 was found in Barachois Pond Provincial Park on March 12, 1986, and just outside the Park on March 18, 1986. This is a straight line distance of 40 kilometers from his original capture site. Male #30 was found at the junction of highway 47 to Stephenville and the Trans-Canada Highway on March 18, 1986. On June 16, 1986, he was found near Gallants Hill, also a straight line distance of 40 kilometers. Marten #50 left the study area in October 1986. In February 1987, he was captured accidentally near the Buchans power line corridor on the east side of Grand Lake, a straight line distance of 34 kilometers. Marten

#62 was first captured on the study area November 1, 1986; he probably left the study area for good in December 1986. In November 1987, he was accidentally captured near Big Gull Pond just east of the Trans-Canada Highway near Georges Lake. This is a straight line distance of 24 kilometers, although he had to go around Grand Lake to reach this area. Marten #68 was first captured on the study area May 23, 1987. In January 1988, she was accidentally trapped near Gallants Hill.

Demography

Age-related demographics

Kits that were trapped usually left the area as transients, while yearlings were more likely to remain and colonize an area. One of 16 kits captured (#32) managed to establish a permanent home range on the study area during her first year. However, at least five (#'s 28, 32, 42, 46, and 49) of ten yearlings established permanent home ranges during their first two years of life. Female marten in Newfoundland probably first breed successfully during their third summer and produce their first litter when they are three years old. No yearling females encountered produced a litter.

Age ratios

Throughout most of the study, adults and yearlings were found on the study area in approximately a 1:1 ratio (Table 5). The exception was during summer 1987 when we could document the presence of no yearling residents. The high mortality during the previous fall and winter (see below), as well as the disruptive effects of road building and logging operations the previous year from June to November, may have had some effect. However, one marten (#69), appeared to be colonizing part of the study area

Table 5. Age and sex ratios of marten at Little Grand Lake.

Season	<1 yr	1-2 yrs	>2 yrs	Unknown	Total
Winter 1986					
all captured[1]	3(0/3)[2]	4(4/0)	4(2/2)	3(2/1)	14(8/6)
residents	2(0/2)	1(1/0)	3(1/2)	_	6(2/4)
Summer 1986					
all captured	4(3/1)	5(2/3)	5(3/2)	1(0/1)	15(8/7)
residents	4(3/1)	5(2/3)	4(2/2)	_	13(7/6)
Fall 1986					
all captured	13(6/7)	5(2/3)	5(2/3)	2(2/0)[3]	25(13/12)
residents	0	5(2/3)	5(3/2)	_	10(5/5)
Winter 1987					
all captured	2(0/2)	3(2/1)	2(1/1)	-	7(3/4)
residents	0	3(2/1)	2(1/1)	-	5(3/2)
Summer 1987					
all captured	0	2(1/1)	3(3/0)	2(0/2)[4]	7(4/3)
residents	0	0	3(3/0)	-	3(3/0)

[1]Includes marten captured in November 1985.
[2]Males/females.
[3]Age confirmation for one of these animals is pending.
[4]Age confirmation for these animals is pending. All are believed to have been born in 1986.

during late summer and fall 1987. At no time during the study did adult females occupy all the available habitat on the study area.

Sex ratios

Sex ratios were not significantly different from 1:1 for all age classes throughout the study. From November 1985 through August 1987, 20 males and 20 females were captured on the study area; 16 males and 15 females were captured on the study area in 1986, while 4 males and 7 females were captured in 1987, with some individuals captured in more than one year. The skewed sex ratio of 1987 may have resulted from the total absence of resident females during

summer 1987, allowing more transient females to use the area. Sex ratios remained mostly constant at 1:1 for each age class through most seasons except summer 1987, and for all classes combined (Table 5). By the spring of 1987, no females could be found on the study area. All females resident in 1986 either died or disappeared by spring.

Productivity

Two female marten (#34 and #39) produced litters on the study area in 1986; no female marten were known to produce litters on the study area in 1987. Female #34 produced at least two kits in 1986 (#50 and #51) and possibly a third, #52. Only two kits (#48 and #53) were captured within the home range of female #39. An intensive effort was made to capture kits on the study area once they became independent from their mothers in July. It was thought that all kits produced by females #34 and #39 in 1986, and survived until independence, were captured. If this is true, female #34 may have produced three kits, while female #39 produced two in 1986. Female #34 was five years old in 1986; female #39 was four years old. Two yearling females (#32 and #49) residing on the study area during the summer of 1986 did not produce kits. During 1987, it appeared there were no reproductively active adult females available for mating during the summer breeding season.

Mortality

Marten deaths during the study were attributable to at least four factors. Disease, predation, accidental trapping, and handling were the causes of 16 of the 17 marten deaths on the study area. Two others may have died, but we were unable to confirm their status. Table 6 lists the numbers, ages and sexes of those dying by each factor. Table 7 lists the individuals

Table 6. Mortality factors and numbers of deaths by age and sex class for marten at Little Grand Lake.

Mortality factor	Age				Total
	Kits	Yearlings	Adults	Unknown	
Disease	5(1/4)[1]	1(0/1)	3(2/1)	1(1/0)	10(4/6)
Predation	1(0/1)	-	1(0/1)	1(1/0)[2]	3(1/2)
Handling related	2(0/2)	-	-	-	2(0/2)
Dispersed, accidentally trapped[3]	1(1/0)	-	-	-	1(1/0)
Died, cause unknown	1(0/1)	-	-	-	1(0/1)
Suspected	-	-	-	2(2/0)	2(2/0)
Totals[4]	10(2/8)[4]	2(1/1)	4(2/2)	2(2/0)	17(6/11)

[1]Males/females.
[2]Suspected to be a kit.
[3]Two additional marten, #62 and #68, were accidentally trapped after this study ended.
[4]Does not include suspected deaths.

that died. In addition, one marten (#57) outside the study area died from disease. Each factor is discussed below.

Disease. The most significant mortality factor encountered during the study was a disease outbreak in fall 1986. Post-mortem and lab analysis of tissue samples for six animals resulted in a tentative diagnosis of viral non-suppurative encephalitis. The first suspected disease death occurred September 19, 1986; the last recorded, November 1, 1986. Ten marten are suspected of dying of encephalitis. Marten of all age and sex classes died (Table 6) including five kits, one yearling,

Table 7. Cause of death of individual marten inside and outside study area.

	Number		Individuals
LITTLE GRAND LAKE STUDY AREA			
Disease	10	LGL	29,35,39,43,48,56, 58,59,60,61
Predation	3	LGL	34,65,66
Handling related deaths	2	LGL	63,67
Dispersed, accidentally trapped	1	LGL	50
Died, cause unknown	1	LGL	36
Fate unknown	15	LGL	30,31,32,33,37[1],38, 40[1],41,45,49,51,52, 53,55,64
Alive at end of study	8	LGL	28,42,46,62[2],68[3],69, 70,71
OUTSIDE THE STUDY AREA			
Disease	1	LGL	57
Fate unknown	4	LGL	13,44,47,54

[1]Unconfirmed death.
[2]Accidentally trapped 11/87 near Big Gull Pond.
[3]Accidentally trapped 1/88 near Gallants Hill.

three adults, and one marten of unknown age. The sex ratio of those dying on the study area was four males to six females. Proportionally, approximately equal numbers of deaths were noticed among adults and kits, but fewer among yearlings. One of five known yearlings captured on the study area died, while three of five known adults and five of eleven kits died. Two other kits were captured during this time, but were not radio collared; their fates are unknown.

Predation. Predation upon marten resulted in three deaths on the study area during fall 1986 and winter 1987. Marten #65 was captured and radio collared December 4, 1986. He was probably killed and appeared to have been consumed by a raptor or raven on either December 5 or 6. His radio collar and a tuft of fur were found on a limb 20 feet high in a tree 2.3 km from the capture site. Marten #66 was first captured January 29, 1987. On February 11, 1987, her radio collar was found; it appeared that she had been consumed by a red fox (Vulpes). Marten #34 was found dead in a subnivean cavity on March 31, 1987. Post-mortem examination revealed internal organ damage and hemorrhaging caused by physical trauma, indicating she may have escaped a predator only to die later from her injuries. No animal tracks were seen in the area.

In addition to these incidents, a failed predation attempt by a hawk owl (Surnia ulula) was witnessed November 1, 1986. The owl made three passes at marten #32 while she was in a tree. On the third pass, she fell ten feet to the ground and immediately darted into a nearby hole, apparently uninjured.

Handling-related deaths. Two marten deaths apparently were handling related. Female #63 was first captured and radio collared November 5, 1986. She was found dead in a cavity beneath a tree stump November 29, 1986. Her radio collar had slipped over her shoulders and had pinned the upper portion of her front legs to her body, making normal walking impossible. She appeared to have died from starvation. Marten #67 was first captured March 13, 1987; she died March 15, 1987. She is believed to have died from a combination of chronic starvation and hypothermia. When encountered in a trap the morning of March 15, she was partially wet;

the previous night's temperature did not get below freezing. At her first capture on March 13, she weighed 625 grams, a very low weight for a female marten. At her death she weighed 550 grams. During these three days she was captured four times. Her behavior when released from the traps indicated she probably was starving. Additional food was twice left for her upon release to ensure she did not become a trap mortality. It is very possible she would have died before the onset of spring.

Accidental captures. Marten #50, a kit, was accidentally trapped in February, 1987 near the Buchans power line corridor on the east side of Grand Lake, approximately 34 km northeast of his maternal range. Though he was captured in a live trap, he was dead when encountered by the trapper. He dispersed from the study area in October, 1986. Marten #62 was accidentally trapped in November 1987 near Big Gull Pond approximately 24 km west of the study area. Marten #68 was accidentally trapped near Gallants Hill in January 1988, approximately 31 km west of the study area. The latter two mortalities were not included in subsequent calculations since the deaths occurred after our study ended. These are the only known instances of study animals being accidentally trapped, though several marten are usually captured each season outside the "no trapping" area. All three known accidental captures were outside the PMSA.

Unknown Causes. Female #36 was captured and radio collared January 23, 1986. She is believed to have died shortly afterward. The cause of death is unknown.

In addition to these deaths, two other marten may have died. A mortality signal was picked up for marten #40, but we were unable to recover either the radio collar or carcass. Marten #37 was captured and

collared January 23, 1986. He was last located in February, 1986. His fate is unknown.

Seventeen of 40, or 42.5 percent, of the marten captured on the study area between November 1985 and August 1987 died by the end of the study in August 1987. Twenty percent (8 of 40) were known to be alive at the end of the study, while the fates of 37.5 percent (15 of 40) were unknown. Disease contributed 59 percent of the known mortality (10 of 17 deaths); predation, 17.5 percent (3 of 17 deaths). Handling related deaths accounted for 11.5 percent (2 of 17 deaths), while accidental capture and death of unknown cause each contributed six percent for a total of 2 of 17 deaths. A 42.5 percent mortality over 22 months yields a minimum average annual mortality rate estimate of 0.232 for the entire population.

The fates of 25 marten captured on the study area are known; 17 died and 8 were alive at the end of the study. Fifteen of 23, or 65 percent, died of "natural" causes (all factors except handling) during the course of the study. If the marten whose fates are unknown (n=15) experienced similar mortality, then 65 percent of all marten captured on the study area died by the end of the study; 43 percent died from encephalitis during fall 1986. This yields an average annual mortality rate estimate of 0.356 for the entire population.

DISCUSSION

Effects of Disease and Low Prey Base on Marten

During the fall of 1986 and the winter of 1987, 4 of 9 known resident marten with established home ranges on the study area died. An additional 9 marten died on the study area during this period. Three were probably a result of predation, the rest a result of an encephalitis outbreak during fall 1986. Several lines of evidence suggest that the high marten mortality during the study was not confined to our intensive study area. Marten #57 was found alive but ill on the Bottom Brook road south of Little Grand Lake and outside the study area; she later died of encephalitis. Only three sets of tracks from uncollared marten were seen throughout the study area during winter 1987. Bait stations placed both on the intensive study area and on the area immediately west of the Buchans Plateau received no use by uncollared marten. During the winter of 1986, six new non-resident marten were captured; however, during the winter of 1987 only two new non-resident marten were captured on the study area. Furthermore, we documented no colonization of the study area by new marten in early 1987, although one marten may have begun colonization in August 1987 when the study ended.

If the encephalitis outbreak of fall 1986 was not just a local phenomenon, colonization of vacant home ranges would be slow. The pool of transient marten usually available for colonization may have been drastically reduced. Furthermore, reproduction may be severely reduced for the next few years. By spring 1987, all female residents of the study

area were either dead or no longer resident; we were unable to document kit production during 1987. Vacant home ranges will eventually be filled, but it may be two years post-colonization before younger females produce offspring.

The meadow vole population on the study area plummeted at the same time the marten disease outbreak occurred during fall 1986. By spring 1987, meadow voles, the most important prey item for marten, were almost nonexistent on the study area. How this affected home range sizes of individual marten is unknown. Predator response to a food-poor environment is variable. Home range size and time spent foraging will vary depending on energetic constraints. The death of a conspecific occupying a contiguous home range as well as a drastic decline in prey availability both may have influenced marten #28's expansion into the previously occupied range of #29. Number 28 was the only collared marten who doubled his home range and core area size in 1987. It is not known if the low prey base played a part in the home range shift of female #49 during winter 1987.

The high number of apparently transient marten captured during the fall of 1986 may have been partially a result of the sudden reduction in the meadow vole population. Kits routinely disperse in fall (Archibald and Jessup 1984, our data), but the declining prey base may have augmented the number of dispersers as well as the rate and distance of dispersal. In Labrador, a sharp decline in rodent populations and a large increase in both marten sightings and the number of marten trapped occurred during fall 1986. Annual marten harvests in Labrador from 1983 to 1985 ranged from 1200 to 1900; however, 5000 marten were trapped in 1986 with no

increase in trapping effort from previous years (Phillips pers. comm. 1987). The dramatic increase in marten sightings appeared to be a result of a highly mobile population under stress rather than an increased population. No yearling animals were represented in 114 marten carcasses examined in 1985-86. A much higher percentage of the population appeared to have dispersed during fall 1986. Some probably had abandoned "permanent" home ranges. Phillips (pers. comm. 1987) and Lemon (pers. comm. 1987) indicated serious declines in small mammal populations in Labrador in 1986. Part of the influx of new marten through our area during fall 1986 may have resulted from the declining prey base. The sudden decline in prey densities and the high marten mortality caused by the disease outbreak present a new concern for Newfoundland marten.

Clear-cutting Effects on Marten

Marten preference for mature coniferous or mixed coniferous forest with high overstory density is well documented in North America. Hargis (1982) and Spencer et al. (1983) in California, Clark and Campbell (1977) in Wyoming, Koehler and Hornocker (1977) and Koehler et al. (1975) in Idaho, Raine (1983) in Manitoba, Douglass et al. (1983) in the Northwest Territories, de Vos (1952) and Thompson (1986) in Ontario, Steventon and Major (1982) and Soutiere (1979) in Maine, Bateman (1986) and Snyder and Bissonette (1987) in Newfoundland all found this to be the case. Buskirk (1983) in Alaska indicated that a mosaic of vegetation types including non-forested areas comprised important marten habitat. His data indicate that 92 percent of his relocations were in coniferous or mixed forests, although these cover types comprised only 52 percent of his study area.

In Alaska, Vernam (1987) studied habitat use by marten in an area that was 60 percent burned eight years before. He found that marten used both burned and unburned habitats, but unburned white spruce and mixed woods were preferred while wet meadows were avoided. He also reported that some form of overhead cover was necessary when marten used burned habitats. Wind thrown trees on his study area apparently provided that cover. In the Southwest Brook area of Newfoundland, Bateman (1986) found that marten preferred mixed balsam fir-white birch stands with overstory densities of at least 76 percent. This forest type also had the highest abundance of meadow voles. Our data show virtually no use of clear-cuts up to one year old by marten even though higher populations of voles appear to exist there. These observations, coupled with our data on predation, suggest that avoidance of more open areas may be due at least in part to cover requirements as protection against avian predation.

Several studies have shown that clear-cutting adversely impacts marten populations. Marten in Wyoming did not use one-year-old clear-cuts (Clark and Campbell 1977). In Maine, marten used the uncut forest heavily in summer and winter, making only light use of clear-cuts in the late summer when berries were present (Steventon and Major 1982). Marten tolerated extensive areas of 3- to 16-year-old clear-cuts. However, Soutiere (1979) found that marten were three times more abundant in uncut areas than in areas that had been 50 percent clear-cut and 25 percent selectively cut. Thompson (1986) found clear-cuts to be sub-optimal marten habitat. Marten in uncut areas encountered two to three times more prey items than those in extensively clear-cut areas and killed 21 to 178 percent more biomass of prey than marten in cut areas.

In Newfoundland, Snyder and Bissonette (1987) found that marten seldom used clear-cuts; instead they used the uncut forest and residual stands within the clear-cuts. From June to December 1983, 18 marten were captured on the 140 km^2 study area in 3587 trap nights. Clear-cuts represented 41 percent of the study area. From June to December 1986 of the present study, 23 different marten were captured in 1910 trap nights on an area of approximately 55 km^2. Our study area was immediately east of Snyder and Bissonette's area and was nearly uncut. Some marten on Snyder and Bissonette's study area probably were not captured during their study (Snyder, pers. comm. 1987). Two radio collared marten present on our study area and possibly other uncollared marten remained uncaptured from June 1986 to December 1986 despite efforts to trap them.

Clearly, marten densities are much lower in extensively clear-cut areas of Newfoundland than in the remaining uncut areas. Furthermore, it is obvious from our study that marten in Newfoundland very rarely use clear-cuts during the first year after cutting, and only minimally use residual patches of forest in clear-cuts up to 23 years old (Snyder and Bissonette 1987). There is no doubt that clear-cutting extensive areas has caused severe declines in the marten population of Newfoundland.

Marten Population Projections for the Study Area

Using information gathered from this study, it is possible to project how many resident marten with established home ranges the environmental assessment area (EAA) might reasonably be expected to support. According to forest inventory charts, and as best as we can determine, there is approximately 561 km^2 of marten habitat within the EAA. Marten habitat is

defined as stands of mature softwood or mixed-wood. If our calculations are correct, Glover Island accounts for 106 km^2 of this total; the remaining 455 km^2 is found throughout the EAA. Mean home range sizes for resident male and female marten were calculated from the radio collared marten in this study. Using harmonic home range sizes from Table 4, we calculated a mean female home range size of 6.64 km^2. Four home ranges of female marten were used since these were the only females considered to be residents: marten #32, #34, and #39 (before logging) and #49 (during logging). Similarly, a mean home range size of 9.19 km^2 was calculated using established home range sizes (before logging) of males #28, #29, and #42. Home ranges for these marten were well established and represent values as close to the true state of nature as is possible with this sample size. We believe our figures are conservative because the effects of logging, marten disease, and the reduced prey base were not yet manifest. Home range sizes used in this report have had large areas of bogs, barrens, and lakes subtracted from the calculated total. Although these areas are included in all established home ranges and may be important, they are used very little. We divided the remaining available forested area by the home range sizes of males and females separately. Home ranges overlap between sex, but not extensively within sex. We calculated that Glover Island can support 12 male marten and 16 females for a total of 28 resident marten. Similarly, the remainder of the assessment area will support 50 males and 69 females for a total of 119 resident marten. Taken together, the assessment area will support 62 males and 85 females for a total of 147 resident marten. If our

assumptions are correct, these projections are probably close to a maximum resident population size for the assessment area.

Although a resident population of 85 females is projected for the assessment area, the effective breeding population is probably much smaller. During our study, the age ratio of resident females was usually one adult to one yearling. If this ratio is representative, half of the resident females present at any given time would be too young to produce kits. Furthermore, some female home range "vacancies" probably exist each year and some adult female marten may not produce offspring every year. It is possible that as few as 43 females on the assessment area may produce a litter for any given year. If litters average 2.5 kits, 108 kits might be produced in any given year.

Glover Island is isolated with probably very little marten ingress or egress. Dispersal to and from Glover Island is apparently minimal due to the width of Grand Lake, the narrowest point being approximately 750 meters across. Even when frozen, the lake still presents a formidable barrier for marten to cross. Distance, however, is only one measure of isolation (Harris 1984). Absolute distance is always relative to the requirements of the species. Sedentary versus migratory habits of the species also influence "isolation." Finally, habitat specificity and tolerance for environmental variation influence the effects of habitat isolation. Marten specificity to old growth and reluctance to cross wide expanses of open areas contribute further to the isolation of Glover Island. Small isolated sub-populations with little opportunity for dispersal are more prone to extinction and their re-establishment will be slower than for a less isolated sub-population (Fahrig and Merriam 1985).

Isolated sub-populations also "contribute less" to the survival of the entire population, suggesting that effective population size of the entire assessment area may be substantially less.

During fall 1986 and winter 1987, 4 of 9, or 44 percent, of the known residents with established home ranges on the study area died. If our sample is representative and if similar mortality of residents occurred during this time throughout the assessment area, 65 of the projected 147 residents died. This suggests only 48 of the female residents survived until spring 1987, by extension, nine on Glover Island and 39 on the remaining area. If only half of the surviving females produced kits during spring 1987, five litters for a total of 13 kits were produced on Glover Island and 20 litters for a total of 50 kits were produced on the mainland. We, of course, cannot be certain of how representative our sample is of the entire population. We have no measure of population variance. However, to the extent our study area is representative, these are reasonable projections of what the current marten population status on the assessment area could be.

These projections lead us to question whether the assessment area alone can sustain a viable marten population. Additional areas will be needed to support a system of inter-connected sub-populations to ensure marten survival in Newfoundland. These areas probably need not be refuges where no timber cutting is allowed, but special management of timber harvesting will be necessary.

PART III. RECOMMENDATIONS

Marten were listed as "threatened" with extinction by COSEWIC in Newfoundland in April 1986. Despite several management strategies in the past, including no-trapping restrictions since 1934 and the establishment of a "Pine Marten Study Area" in 1973, there has been no detectable increase in marten abundance or distribution. Snyder and Hancock (1985) estimated marten populations on the island to be between 631 and 875 animals with the highest density in the Grand Lake-Little Grand Lake area (Figure 2). Our latest estimates suggest perhaps no more than 150 resident marten inhabit the assessment area.

Several studies (Seton 1929, Marshall 1951, de Vos 1952, Lensink 1953, Hawley 1955, Francis and Stephenson 1972, Koehler et al. 1975, Clark and Campbell 1977, Koehler and Hornocker 1977, Mech and Rogers 1977, Soutiere 1978, Snyder 1984, Bateman 1986, Douglass et al. 1983, Hargis 1982, Hawley and Newby 1957, Raine 1983, Pulliainen 1981, Spencer et al. 1983, Weckwerth and Hawley 1962) have indicated the importance of mature coniferous or mixed forest to marten. Our study corroborated the value of mature forests to marten.

Even though Sorex appeared to be several times more abundant in regenerating cutovers, our data show clearly that marten used these areas minimally and preferred to remain in the forested areas. Snyder and Bissonette (1987) found in this same study area that marten use of clear-cuts less than 10 years old was minimal. They noted little evidence of marten use in clear-cuts 10 to 23 years old. On the very few occasions we

observed marten use of clear-cuts, only once did a marten cross a clear-cut more than 200 meters wide without using residual tree clumps. Marten did not appear to be hunting within the clear-cuts. Their tracks indicated they travelled as quickly as possible across the opening using whatever cover was available, usually small pockets of uncut non-merchantable timber. The distance between tracks indicated a running gait, and trails were direct, with little wandering characteristic of hunting. Similar observations were made by Soutiere (1978), Snyder (1984), and Koehler et al. (1975).

Mature forests not only provide the greatest cover for marten, but also the greatest opportunity to catch rodents (Koehler et al. 1975). Greater access to the subnivean zone can be found during winter in forested areas where natural crevices form around objects protruding from the snow. In cutover areas, the absence of trees and the build-up of snow in winter considerably reduces the availability of prey at a time when food is critical. Slash appears to provide little vertical relief aiding access to the subnivial zone.

Several factors have contributed to the decline of marten in Newfoundland. Logging has often been cited continent-wide as having the greatest effect on marten populations (Koehler et al. 1975, Soutiere 1979, Campbell 1979, Grakov 1972, Major 1979, Snyder 1984, Thompson 1986, Clark and Campbell 1977, Steventon and Major 1982, de Vos 1952). These authors reported clear-cuts were detrimental to marten populations and showed that marten numbers were reduced in areas of timber harvest. Bateman (1980) recommended that clear-cuts not be allowed in areas where marten are threatened.

Management strategies to maintain or increase marten populations have been suggested. In Minnesota, a closed trapping season appeared to provide adequate protection; the population increased despite accidental catches in sets for other species (Mech and Rogers 1977). This may have been due in part to regenerating clear-cuts. The increase in marten numbers after 1970 was probably environmentally related and not a direct result of closed trapping seasons; a sharp increase in marten also occurred in Ontario at this time. In Ontario, de Vos (1952) recommended the creation of refuges from which marten could disperse.

In Newfoundland, despite the closure of the marten trapping season since 1934, marten number and distribution have continued to decline. To date, no permanent refuge for marten has been created in spite of their precarious situation. Wildlife Division personnel hoped that the Pine Marten Study Area (PMSA), established in 1973, would act as a refuge in which marten would increase and eventually disperse and colonize other areas of suitable habitat. This expectation does not appear to have been realized. Marten have not increased appreciably in numbers or distribution. The most likely reason is that even though marten are protected in the PMSA, their habitat is not. With increased logging activity in and around the PMSA, marten habitat has been disappearing at an average rate of 4000 hectares per year (John, pers. comm. 1985 in Snyder 1985). Additionally, prey density fluctuations could well dampen significant population increases.

Two national parks in the province that could function as marten refuges do not contain large numbers of marten. Reintroductions into one of them, Terra Nova National Park (Bateman 1985), and also into the head

of the Lapoile River (Mayo 1976a), and Siviers Island (Porter 1976), all appear to have had limited, if any, success, leaving the Grand Lake-Little Grand Lake area and possibly the Main River area in western Newfoundland as the only known remaining areas still containing a remnant population.

During the 1960's, red squirrels and eastern chipmunks were introduced into Newfoundland to help increase the food base of marten (Hancock, pers. comm., 1988). Despite this, marten populations have not expanded as hoped. The introduction of ruffed grouse (Bonasa umbellus) and spruce grouse (Dendragapus canadensis) for other purposes likewise has not provided a readily available and abundant food resource for marten.

Soutiere (1978) warned that clear-cutting should not be allowed in areas essential for survival of remnant populations of marten. It was realized almost 40 years ago (de Vos 1952, Miller et al. 1955, Newby 1951) and more recently (Major 1979, Koehler et al. 1975, Soutiere 1978) that habitat management was required in some areas to maintain suitable habitat for marten. However, many recommendations for timber harvesting to favor marten habitat were considered secondary to harvest regulations and trapping restrictions (Bateman 1980). Harvest regulations and trapping restrictions have failed to prevent the marten population from declining in Newfoundland. It is time to consider the most effective alternative strategy: habitat management.

One scenario, with the preservation of marten in Newfoundland in mind, is presented. It is based on two well documented facts: 1) marten are area sensitive species that need large tracts of mature coniferous or mixed forests, and 2) large clear-cuts are detrimental to marten.

Scenario

To maintain the marten population at its present level in Newfoundland and to provide conditions that promote reasonable hope that population levels may one day gradually increase, the following actions, in our opinion, are needed.

Establish a two-zone management area consisting of the environmental assessment area as the core area (innermost zone, see Figure 1), and a second zone coincident with the no trapping/no snaring area (PMSA). We recommend the boundaries of the PMSA be extended to include the EAA within its boundaries. The entire management area may well be considered to be a "greater marten ecosystem management area" much in the same sense, but on a smaller scale, as the Yellowstone system, although no specific recommendations are made for a third "defacto" zone of indefinite size surrounding the area.

(a) No further logging should be conducted within the Environmental Assessment Area (EAA) (Figure 1). In our opinion, based on our studies and analysis and on the burden of literature, any future logging in the EAA can only adversely affect pine marten and result in a further decline in their numbers. We suggest the "no trapping" area be extended to the north and northwest to encompass the E.A.A. in such a manner so as to provide a buffer zone between the PMSA and E.A.A. boundaries.

(b) Logging may be conducted outside of the core area (EAA) within the second zone (no trapping/no snaring zone) if strict adherence to certain guidelines given in the section titled "Recommendations for logging" are followed (see below). If the

guidelines are followed in good faith, forest activities in zone 2 should provide an environment compatible with habitat requirements for marten, and the species stands a reasonable chance of sustaining and probably increasing its present population level in Newfoundland.

(c) We strongly urge that the "greater marten ecosystem management area" be managed in a cooperative manner by CBPPL and the Newfoundland and Labrador Wildlife Division and other pertinent agencies, such as the Department of Environment. Most of the area is Crown land and therefore of high public interest. The Wildlife Division manages the wildlife resource, CBPPL harvests in the area under exemptions and leases granted by the government. We urge a LANDSCAPE APPROACH to management (see below) that ensures the survival of marten and other species in the area as well as provides a sound economic venture for CBPPL.

(d) We recommend establishing a multidisciplinary advisory team to oversee the landscape management process. Members should include CBPPL and Wildlife Division personnel, as well as perhaps representatives from the departments of Environment and Forestry and representatives from the local community and private conservation groups. The committee would provide input and advice concerning ecosystem values to the preparation of annual cutting and salvage plans on Crown land. Crown land is a public resource. Input from diverse constituencies will ensure that all perceived needs are addressed.

(e) We also suggest that a qualified individual be assigned the responsibility to oversee placement of roads and field cutting operations to ensure compliance with existing regulations and recommendations. The person should be responsible to both CBPPL and the Wildlife Division, and should be required to report to the advisory committee on an agreed-upon schedule and to any member of the advisory team as requested. Effective planning involving several parties is only effective to the extent that agreed-upon plans and methods are carried out. McFarland (1976, p. 58) states that planning and control are really two sides of the same coin; "The most effective control is that built into the planning effort." The presence of an on-sight overseer encourages managers to govern activities so as to achieve the desired goal. It also provides well-intentioned managers with a second control for their operations.

We envision the EAA functioning as a refuge for marten from which animals can disperse. There is, however, no evidence to suggest that this has occurred in the past. Successful dispersion requires sufficient recruitment within the E.A.A. to allow dispersal, and that dispersing marten find suitable habitat outside of the PMSA. It is our opinion that adequate recruitment will be greatly enhanced by restricting cutting within the EAA. The success in finding suitable habitat outside the EAA will depend on the availability of and access to old growth timber. Since the middle 1970's, several authors have suggested that large contiguous areas be conserved (Diamond 1975, Sullivan and Shaffer 1975, Whitcomb et al. 1976, Lovejoy et al. 1984, Wilcox and Murphy 1985). Alternatively,

several investigators have provided evidence that, if total number of species is to be maximized, then several smaller-sized parks might be the most effective strategy (Simberloff and Abele 1982, Gilpin and Diamond 1980, Quinn and Robinson 1987, and Quinn and Hastings 1987). Strategies used to maximize total species diversity, however, can run counter to the needs of area sensitive species. McLellan et al. (1986) suggested that optimum conservation strategies depend upon the needs of area sensitive species and the extent to which fragmentation has already occurred. Large reserves are necessary to protect extinction-prone species with stringent habitat requirements. Soule et al. (1979) and Shaffer and Sampson (1985) have pointed out the need for large habitat areas to maintain secure populations of carnivores. Lensink (1953) did not recommend establishing refuges in Alaska because so much area was available at that time and relatively little was disturbed. He did recommend that when refuges are needed, the cruising radius of the species be taken into consideration. Marten in Newfoundland have been found 40 km^2 distant from where first captured. Temple (1986) has emphasized that even though there is a strong association between the presence and absence of birds sensitive to habitat fragmentation and the total area of forest fragmented, there exists an even stronger correlation between population size and core area size. In western Newfoundland, habitat needs of marten require that sufficient areas of undisturbed old growth be set aside. Our recommendations for core area is within the range suggested for establishment of preserves. The surrounding area, zone 2, managed on a landscape basis to favor marten, will provide habitat and travel routes through which marten can seek new areas. We are cognizant of the role that the depauperate and

often cyclic nature of the prey base plays in determining marten populations. This only strengthens the necessity to provide ample habitat to support a population of viable size.

Recommendations for Logging

To provide an environment compatible with habitat requirements for marten in the area surrounding the marten refuge (zone 1), a cutting rotation that leaves large areas of mature coniferous forest standing at all times is recommended. In no case should uncut residual stands of timber be less than 15 hectares in size (Snyder and Bissonette 1987). They should be interconnected spatially, either by close proximity (less than 200 meters apart) so that movement can occur between them, or by "corridors" along which animals can move. Permanent corridors in zone 2 should be maintained. To avoid having large expanses of clear-cut between two or more stands of old growth forest, we recommend that no clear-cut be more than 500 meters wide. The idea here is to have a matrix of old growth forest with small cutover areas interspersed throughout that matrix and not vice versa. Marten do not respond to highly dissected forest so we take the opposite approach and suggest that it is the cutting that needs to be highly dissected, leaving large areas of intact undisturbed forest. The more widely dispersed the cuts are, the better the situation for marten. However, the increased road network needed for widely spaced cuts may well offset at least some of the benefits gained. We recommend that road construction, especially capital or permanent roads, be kept to a minimum. Small disturbed areas may require less time to reestablish cover and food than do large areas (Koehler et al. 1975). Regardless,

smaller clearings are less restrictive to marten movements, especially during the winter when slash, which could serve as shelter, is covered with snow. Smaller regenerating clearings can promote higher lagomorph density and availability to marten.

Any stands of uncut timber separated by more than 200 meters should be connected by corridors consisting of continuous closed canopy forest and be at least wide enough to resist blow-down and provide shelter for marten. Harris (1984) suggested that buffer zones along streams, rivers, ponds, and lakes could function ideally as corridors connecting uncut stands of old growth forest. Riparian zones have been noted to be the most productive of all habitat types (Thomas 1979). They are not only beneficial to marten, but to many other species as well. Siltation and consequent degredation of water courses caused by erosion can be greatly reduced by the existence of buffer zones along waterways. We therefore recommend that riparian zones be utilized as corridors wherever possible. Their width will depend on the size of the water channel. We suggest a 100 meter buffer zone (50 meters on each side) along streams and 200 meters (100 meters on each side) along major water channels such as rivers, ponds, and lakes. Where it is impossible to use riparian zones as corridors, the corridor that is left should be at least 200 meters wide.

Landscape Management

CBPPL is faced with an onerous task. Shareholders expect a generous return on their investment. They expect cost effective management. The mill provides a large share of the economic base for the town of Corner Brook and the surrounding communities and has done so since the mid-1920's

(Horwood 1986). Pressures exist to modernize in order to remain competitive in a tough market. The recent troubled history of the mill and the agreements made in order to get the mill operating again provide the real political and economic backdrop against which environmental concerns need to be evaluated.

Nature herself may dictate forest management decisions and priorities. Spruce budworm and hemlock looper infestations have reduced vigor and caused substantial mortality throughout the area. Salvage operations are often necessary to collect dead and dying timber within reasonably short time frames. In Maine, conventional forest wisdom suggested that salvage should be accomplished within a 2-3 year period to make operations profitable. In effect, insect infestations and the damage they do often dictate season-to-season management decisions.

Perhaps the crux of the problem involves the economics of old growth stands. Old growth forests are characterized by low and often negative growth rates. Harris (1984) has pointed out that, economically, these stands represent nearly idle capital. He goes on to state that, even at modest interest rates, excess inventory means large annual costs. At the same time, marten prefer old growth. The literature is replete with documentation. The only known substantial population in Newfoundland inhabits mature timber and is concentrated near Little Grand Lake. Additionally, marten have been designated a threatened species in insular Newfoundland by COSEWIC and thus have attracted national interest. At conflict here are values. Newfoundlanders have a unique opportunity to conserve old growth and the essential character of the land and its wildlife. At the same time, enormous pressures exist to liquidate the

resource. The resource based economy of Newfoundland depends on mining, fishing, and forestry for its economic base. Primary emphasis is placed on economic return, less on environmental values. At the same time, the health, the well being, and indeed the wealth of a community or a country is measured by the abundance and careful management of its natural resources. A company owned by out-of-province interests needs to address the perception by Newfoundlanders that their resources are being exploited. Long-term community and province interests need to be a part of the company's overall strategy. In our opinion, it is possible to conduct economically rewarding forestry operations and still provide for the health of the land and its wildlife and fishery resources. To do this, however, takes a larger scale approach than has been used in the past. Management on a LANDSCAPE SCALE is required. By a landscape approach, we mean treating the western part of the island as an ecosystem. We mean decisions made taking the entire scope of the Crown lands involved into consideration. We mean area-wide consideration given to where and how salvage or new harvest will occur. We mean decisions based on requirements for conserving the wildlife resource, especially marten, and with concern for erosion and siltation of streams, rivers, ponds, and lakes. We also mean economically-sound decisions that provide excellent environmental public relations potential. These are not incompatible criteria, but what is required is a landscape perspective.

In our opinion, adoption of an effective Geographic Information System (GIS) is essential. GIS methodology employs remotely-sensed satellite information in an interactive computer format. The imagery characterizes forest and other ground cover attributes. Interactive

computer maps are generated from digital information, and the unique spectral signature of each habitat allows the almost limitless capability to assess management options. For example, once the spectral signature of disease-damaged spruce has been obtained, it is possible to sit at the computer and interactively locate all other stands with the same spectral characteristics, i.e., all similar stands of spruce that have disease damage. The time saved and the management options presented make the effort well worth the expense. Updated satellite information allows comparisons with the baseline conditions.

With options provided by a landscape scale assessment of the state of the forest, environmental requirements become but one more set of criteria to be factored into the equation as decisions are made. In effect, CBPPL and the Wildlife Division are in the driver's seat making the decisions rather than being placed in a reactive stance, trying to cope with the limitations of small scale which severely limit one's options and interfere with biologically and economically sound management of the resource.

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APPENDIX I

RESEARCH METHODS

Study Design

The study design incorporates comparisons of marten spatial dynamics and prey base densities on control and experimental plots both before and after forest harvesting. The pre-cutting studies were conducted from January 1986 through August 3, 1986. Pulpwood was harvested on the study area from August 3, 1986, to November 14, 1986. Post-cutting studies were conducted from November 15, 1986, through August 17, 1987. During the course of the study, 28,490 cubic meters of pulpwood were harvested from 259 ha by clear-cutting within the study area. In addition, 4.3 km of capitol road and 2.6 km of forest access road were constructed.

Estimates of Density and Relative Abundance for Prey Species

Microtine rodents were the most important food item in marten diets in British Columbia (Cowan and Mackay 1950), Maine (Soutiere 1979), Alaska (Lensink et al. 1955, Buskirk and Macdonald 1984), California (Zielinski 1981), and the Northwest Territories (Douglass et al. 1983). Additionally, snowshoe hare and red squirrel were found in very low to low densities, respectively, on the study area. Hence, our trapping effort concentrated on the estimation of *Microtus* and *Sorex* densities.

Microtus and Sorex

Densities of Microtus and Sorex were estimated using a trapping web designed by Anderson et al. (1983, Figure 14). The trapping web design was used since it enables density to be estimated using distance sampling analysis methods. Unlike the traditional capture-recapture and removal methods, distance sampling can be used to estimate population density directly, rather than estimating population size and the geographic area separately. In plotless sampling the data are the distances d_1, d_2, ..., d_n to the n entities detected from either a random line or point. Estimation of density is based on the distribution of these distances.

According to Hamar et al. (1971), insectivores and certain rodents are captured very efficiently using pitfall traps and snap traps. Therefore, on each trapping web, two Victor snap traps and one pitfall trap were placed at each trap site (snap traps were placed within 50 cm of the pitfall trap). Victor snap traps were chosen over Museum Special snap traps for two reasons: 1) no difference in vole capture efficiency was found between the two types of traps in a pre-study we conducted, and 2) Victor snap traps were less expensive. Snap traps were baited with peanut butter while pitfalls were not baited. Traps remained open for four nights. All traps were tended daily and bait was replaced as needed.

Ideally, live trapping of small mammals would have been preferred over removal trapping; however, the cost of purchasing 2,880 (12 trapping webs x 240 trap sites/web; spring of 1987) Sherman live traps (approximately $10 per trap) was well beyond our budget. By using two Victor snap traps and one pitfall trap at each trap site, it was possible

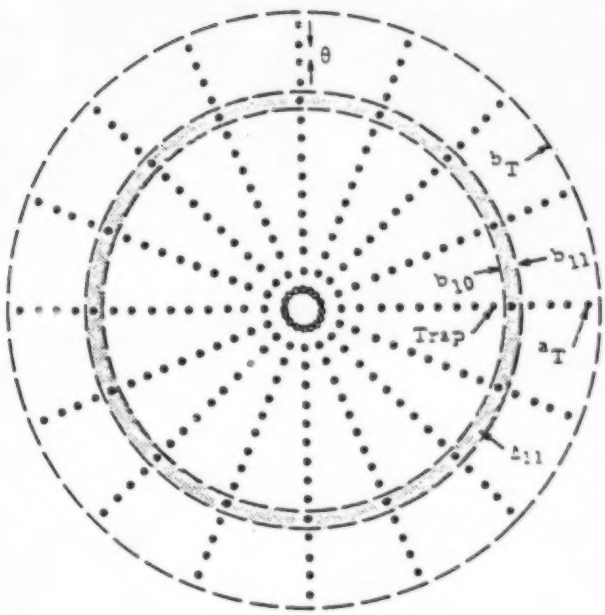

Figure 14. Trapping web with 16 lines (L=16), each of equal length a_i and 15 trap sites per line (T=15) for a total of 240 trap sites (two Victor snap traps and one pitfall trap at each trap site). Trap sites are located along each of the L lines at a distance interval of six meters (θ). Then trap sites are located at the following distances from the web center $a_i=(i-1)\,\theta + \theta/2$ for $i=1,\ldots,T$. The points along each line, halfway between trap sites are denoted as b_i, $i=0,1,\ldots,T$, where $b_0=0$ is the center of the web and b_T is the boundary of the web and lies just beyond the last trap site. Captures in the 11th ring of traps are assigned to the shaded ring Δ_{11} which has area $C_{11}-C_{10}$ where $C_i=\pi(b_i)^2$.

to capture a greater proportion of the small mammal population within the web, resulting in a more accurate estimate of density.

The first trapping series occurred in the spring of 1986 with three webs being placed in a control area (area that would not be cut) and an experimental area (area that would be cut in late summer). In this way we determined whether the control and experimental areas had similar densities of small mammals before logging occurred. The second trapping series took place in the fall of 1986. Three trapping webs were placed in a control area (mature timber) and three were placed in the experimental area (area that had just been cut). The third and final trapping series occurred in the spring of 1987. At this time, three webs were placed in four different habitats: mature timber (the control), a one-year-old cutover, a 13-year-old cutover, and a 23-year-old cutover that had been precommercially thinned. Because removal trapping was used, trapping web locations were different from those used in the spring and fall of 1986, but mature forested areas (the controls) used in 1987 were characteristically similar to those used in the previous year. A brief description of each habitat is given in Table 8.

To keep the effects of environmental factors on the small mammal trapping to a minimum, trapping web locations within habitats were selected so that all trapping webs were as characteristically similar as possible. At each trapping location (web), the following site characteristics were recorded: slope, aspect, soil drainage, dominant tree species, stand age, average DBH, average stand height, stand density, canopy closure, shrub species, shrub height, shrub density, ground cover

Table 8. Habitat descriptions.

Mature timber - This habitat was characterized by mature balsam fir (Albies balsamea), black spruce (Picea mariana) forest with scattered white birch (Betula papyrifera). Average stand age, standard height, and diameter at breast height (DBH) were 76 years, 15 meters, and 20.7 centimeters, respectively. Predominant ground cover species included wood fern (Dryopteris austriaca), bunchberry (Cornus canadensis), twinflower (Linnaea borealis), starflower (Trientalis borealis), creeping snowberry (Gaultheria hispidula), goldthread (Coptis trifolia), and several species of mosses (Sphagnum sp., Dicranum sp., Pleurozium sp., Polytrichum sp., and Lycopodium sp.). Ground cover density was high.

Recent cutover - This habitat was characterized by a few scattered standing white birch. Slash was moderate to heavy. Predominant ground cover species included bunchberry, starflower, goldthread, and several species of mosses (Sphagnum sp., Pleurozium sp., Dicranum sp., Polytrichum sp.). Ground cover density was moderate.

One-year-old cutover - This habitat consisted of scattered standing white birch with light to moderate slash. Predominant ground cover species included wood fern, starflower, bunchberry, and mosses (Sphagnum sp., Pleurozium sp., and Dicranum sp.). Ground cover density was light.

13-year-old cutover - This habitat was characterized by thick regenerating balsam fir and white birch. The area had been cut in 1974 and the average age of the trees on the area was 11 years old. Average stand height and DBH were 2.7 meters and 3.3 centimeters, respectively. Predominant ground cover species included bunchberry, wood fern, violets (Viola sp.), fireweed (Epilobium augustifolium), goldenrods (Solidago sp.), asters Aster sp.), currants (Ribes sp.), and raspberry (Rubus sp.). Ground cover density was high.

23-year-old cutover - This habitat was characterized by regenerating balsam fir that had been precommercially thinned in 1983. The area had been cut in 1964 and the ground was covered with slash due to the thinning. Predominant ground cover species included bunchberry, wood fern, asters, yellow clintonia (Clintonia borealis), false lily-of-the-valley (Mianthemum canadense), and mosses Pleurozium sp., Dicranum sp., and Lycopodium sp.). Ground cover was moderate to high.

species and density, and amount of slash. The number of fallen logs, stumps, and boulders along a two meter strip running north and south of the web center was also recorded.

By opening all the trapping webs during each trapping series simultaneously, the influence of weather on the comparative catches was avoided. Data collected on each web included the following: species captured, line on which the animal was captured, trap site at which the animal was captured, and whether the animal was captured in a snap trap or a pitfall trap. Once collected, data were analyzed by computer (program TRANSECT) to determine densities for each species.

Tamiasciurus hudsonicus

To obtain an estimate of density for red squirrels, a 7x4 trapping grid (50 meter trap spacing) was established in a mature stand of balsam fir/black spruce timber. Tomahawk collapsible wire traps were used, and each trap was baited with a combination of jam, peanut butter, rolled oats, and dried apple. Numbered metal ear tags were placed in both ears of captured squirrels to aid in identification of recaptures. The squirrels were then released.

The number of squirrels captured over a period of 11 days on the grid was divided by the effective area (the grid area plus the area of a boundary strip [width equal to 1/2 the trap spacing] around the trapping grid).

Lepus americanus

The number of snowshoe hare in the study area before and after logging was estimated by counting the number of trails seen during the

winter months. A trail was defined as all tracks belonging to one hare. Therefore, a second trail would only be counted if it appeared at some distant location from the first trail seen.

Scat Analyses

Each scat was examined and the contents (hair, teeth, seeds, feathers, and insect exoskeletons) identified by comparing them to known samples collected earlier. Scat composition was expressed by frequency of occurrence (%). Zielinski (1981) found that determinations of scat contents by percent volume more accurately approximated the ingested weight of prey of various sizes by a marten-sized mustelid than did the percent frequency of occurrence. However, Pulliainen (1981) stated that the two modes of expression give the same order of importance for the main food items. Taylor (pers. comm.) suggests that use of the volumetric technique involves unavoidable errors associated with differential digestion. We chose frequency of occurrence determinations because we were interested in relative importance and because of time constraints.

Capture Techniques

Marten were captured using collapsible National Live Traps (57x15x15 cm). Traps were placed at the base of a tree or in a natural cavity and covered with sheets of bark and vegetation in snow free months and covered with snow during winter to protect captured marten from inclement weather. Traps were checked twice a day. When handling was necessary, marten were immobilized with ketamine hydrochloride injected intramuscularly in the hind leg. Ketamine hydrochloride is a dissociative

psychotomimetic drug separating consciousness from sensory and motor mechanisms. In proper doses it causes anesthesia and analgesia. Data collected upon initial capture of a marten included: location, date, sex, weight, body measurements (total length, tail length, hind foot length), coloration, estimated age (from tooth wear), and reproductive condition (in season). Notes were taken on general condition, behavior, and presence or absence of ectoparasites. Two first premolars were pulled for age determination by cementum analysis (Matson's, Milltown, Montana). The first premolars are tiny and almost vestigial in marten. Marten were tagged with two small metal ear tags (#1 monel, National Band and Tag Co., Newport, Kentucky) and one larger plastic ear tag to facilitate in-trap identification upon recapture. Most marten were fitted with neck radio collars (Lotek Engineering, Aurora, Ontario) weighing approximately 50g with a life expectancy of six to eight months. On subsequent recaptures, date, location, weight, reproductive condition, behavior, and general condition were noted. Ear tags and radio collars were replaced or repaired as needed. Every attempt was made to recapture marten and replace or repair the radio collar once signal strength had weakened.

Marten were trapped initially in November 1985. Trapping resumed in January 1986 and continued into August 1987. Our goal was to capture all marten residing on the study area.

Telemetry Location

Telemetered marten were relocated one to three times daily during the summers and winters of 1986 and 1987. Relocation was less intensive during the spring and fall. Locations were obtained by snow tracking,

trapping, visual observation, and by radio telemetry. A Telonics TS-1 scanner receiver and hand held RA-2AK "H" antenna were used to locate marten by triangulation. Data recorded for each location included: animal number, date, time, X,Y coordinates, whether active or inactive, and proximity to other marten. The degree of accuracy for each location depends in part on how it was obtained. For this reason, the type of location was also recorded (e.g., visual sighting, 3-bearing telemetry location, 2-bearing telemetry location). For visual sightings, behavior and a description of the site was recorded. Daily relocation schedules were designed to minimize autocorrelation of the relocation data and to yield locations from all hours of the day. Marten were monitored from snowmobiles, trucks, all terrain vehicles, and on foot.

Radio collared marten outside the study area were relocated as a matter of course while conducting monitoring runs within the area. Aircraft were used to search for and locate far-ranging individuals. We tried to find all collared marten that left the study area.

Series of relocations, separated by one to three hours, were taken for selected animals in fall 1986 and summer 1987. These "bursts" were taken to provide detailed movement and activity information and to provide information from which the time to statistical independence of relocations could be estimated. Statistically independent relocations are assumed by most methods of home range estimation.

Home Range Analysis

An updated version (1987) of Program Home Range (Samuel et al. 1985a) suitable for use on personal computers was used to analyze home range

data. With this program, the percent-use convex polygon (Michener 1979, Bowen 1982) and the harmonic mean (Dixon and Chapman 1980) methods were used to estimate home range boundaries, sizes, and core areas. For the convex polygon technique the 100 percent utilization contour was used to estimate home ranges for all animals; a 95 percent utilization contour was used with the harmonic mean method. These utilization contours yielded conservative estimates of home range size.

Methods for delimiting home range boundaries and determining home range size fall into two categories: statistical methods relying on an areal distribution of activity loci (a utilization distribution) and non-statistical methods. The convex polygon technique is an example of the latter. With this method, home range boundaries are determined by fitting the smallest convex polygon that encloses all observations. The main advantage of this technique is its simplicity. However, there are two main disadvantages. The first is that estimates of home range size increase as the number of observations used in home range determination is increased. If the home range shape is convex, then size estimates will asymptotically approach the total area used as sample size is increased. The second problem is that home range shape is constrained to be a convex polygon; this is frequently an unreasonable assumption, particularly when habitat is heterogeneous. If the home range is not convex (e.g., U-shaped), the convex polygon technique usually overestimates home range size and gives inaccurate home range boundaries (Anderson 1982). Home range size estimates from the convex polygon method are presented in this report to facilitate comparison to past work where this method was used.

The harmonic mean method of home range estimation is a statistical method based on a utilization distribution calculated from a set of relocations. Percent utilization contours are drawn based on the utilization distribution. The harmonic mean method can define home range of any shape; utilization contours are directly related to the intensity of activity. Within the home range, core areas can be defined by delimiting the areas where activity is greater than expected from a uniform distribution. The harmonic mean center of animal activity is a very close approximation of the true activity center, being more accurate than other activity center calculations (Dixon and Chapman 1980, Lair 1987). A modified version of the original Dixon and Chapman algorithm (Samuel et al. 1985a) incorporating improvements suggested by Spencer and Barrett (1984) is used.

Large areas of lake, barrens, or clear-cuts included within calculated home range and core area boundaries were subtracted from the calculated size to yield "effective" size. Effective home range and core area sizes are used in discussions throughout this report. Although both harmonic mean and minimum convex polygon estimates of home range size and configuration are presented, the harmonic mean estimates more accurately depict reality in all cases except when sample sizes were small. Consequently, the harmonic mean estimates were used in discussions of each animal except in cases where sample sizes were too small. In these cases the minimum convex polygon estimate is more accurate and was used.

Core areas are those areas within a home range where use exceeds that expected from a uniform distribution (Samuel et al. 1985b). Core areas often contain the best feeding areas, den sites, or refuges. Outlier

locations identified by Program Home Range were excluded from home range calculations because of their potential to highly bias home range and core area estimates. Outliers represent infrequent excursions outside of an animal's normal home range. Their exclusion results in a more conservative estimation of home range that more closely approximates normal movements.

Autocorrelation Indices

Three indices were used to test for significant autocorrelation within a data set. Significant autocorrelation usually causes home range estimates to be too small (Swihart and Slade 1985a). The indices used were Psi (Swihart and Slade 1985a), Gamma (Swihart and Slade 1986), and t^2/r^2 (Swihart and Slade 1985b). Explanations of these indices are given below. Consecutive locations used in home range calculations were separated by a minimum time of six hours. If significant autocorrelation was detected, suspected offending locations were excluded and new estimates generated. However, in some data sets significant autocorrelation was unavoidable despite these precautions. Regardless, our estimates of home range are consistently conservative.

The t^2/r^2 statistic is the mean squared distance between successive observations divided by the mean squared distance from the center of activity (Schoener 1981). Swihart and Slade (1985b) use this statistic to test for independence of observations in animal movements, and also present a method to determine the time between successive relocations needed to consider each observation "independent." This statistic is dimensionless and is, therefore, unaffected by home range size.

Gamma is a scalar measure of bivariate autocorrelation (Swihart and Slade 1986). This term is the mean of autocorrelations between X at times i and i-1 and Y at times i and i-1. First order autocorrelation terms but no cross correlation terms are included.

Psi is also a scalar measure of bivariate autocorrelation (Swihart and Slade 1985a). It includes terms for first order autocorrelations and first order cross correlations.

Demographics

Population estimates were made using collared marten. Track observations and bait stations were used in the winter to detect the presence of uncollared marten. Sex and age ratios were calculated using trapping data. Three age classes were used to classify marten: marten less than one year old were classified as kits, yearlings were one to two years old, and adults were two or more years old. Survival of kits, yearlings, and adults was determined from collared marten. Dispersal of collared marten was also noted. Productivity was estimated from collared marten. Litter size estimates were based on the number of kits found to reside within each female's home range from July through September. An intensive effort was made to capture and telemeter kits once they had reached sub-adult size in July.

Disease Occurrence

During fall 1986, a disease caused many marten mortalities on the study area. In an attempt to determine the cause of these deaths and others, post-mortem examinations of recovered carcasses were performed by

Drs. A. Klevorak and D. Chen of the Humber Veterinary Clinic (Steady Brook, Newfoundland) and by Dr. I. Barker of the University of Guelph (Guelph, Ontario). Tissue samples were cultured at Guelph. In addition, blood serum samples taken from living marten on the study area in fall 1986 and summer 1987 were analyzed by Dr. Barker.

APPENDIX II

SMALL MAMMALS AVAILABLE AS PREY

TO MARTEN IN LABRADOR AND NEWFOUNDLAND

Labrador	Newfoundland
Meadow vole (Microtus pennsylvanicus)	Meadow vole
Red backed vole (Clethrionomys gapperi)	Deer mouse
Heather vole (Phenacomys intermedius)	Snowshoe hare
Rock vole (Microtus chrotorrhinus)	Arctic hare
Deer mouse (Peromyscus maniculatus)	Red squirrel
Meadow jumping mouse (Zapus hudsonicus)	Masked shrew
Woodland jumping mouse (Napeozapus insignis)	Eastern chipmunk Tamias striatus
Snowshoe hare (Lepus americanus)	
Arctic hare (Lepus arcticus)	
Red squirrel (Tamiasciurus hudsonicus)	
Northern flying squirrel (Glaucomys sabrinus)	
Starnosed mole (Condylura cristata)	
Northern bog lemming (Synaptomys borealis)	
Labrador collared lemming (Dicrostonyx hudsonicus)	
Masked shrew (Sorex cinereus)	
Water shrew (Sorex palustris)	
Pygmy shrew (Microsorex hoyi)	